

NASA TECHNICAL NOTE



NASA TN D-8028

NASA TN D-8028

SKYLAB MOBILE LABORATORY

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1. Report No. NASA TN D-8028		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle SKYLAB MOBILE LABORATORY				5. Report Date July 1975	
				6. Performing Organization Code JSC-09234	
7. Author(s) Gary R. Primeaux, JSC, and Maurice A. LaRue, Martin Marietta Corp.				8. Performing Organization Report No. JSC S-429	
9. Performing Organization Name and Address Lyndon B. Johnson Space Center Houston, Texas 77058				10. Work Unit No. 948-90-90-89-72	
				11. Contract or Grant No.	
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D. C. 20546				13. Type of Report and Period Covered Technical Note	
				14. Sponsoring Agency Code	
15. Supplementary Notes					
16. Abstract <p>The Skylab mobile laboratory was designed to provide the capability to obtain necessary data on the Skylab crewmen 30 days before lift-off, within 1 hour after recovery, and until preflight physiological baselines were reattained. The mobile laboratory complex consisted of six laboratories that supported cardiovascular, metabolic, nutrition and endocrinology, operational medicine, blood, and microbiology experiments; a utility package; and two shipping containers. The objectives and equipment requirements of the Skylab mobile laboratory and the data acquisition systems are discussed. Processes such as permanently mounting equipment in the individual laboratories and methods of testing and transporting the units are discussed. The operational performance, in terms of amounts of data collected, and the concept of mobile laboratories for medical and scientific experiments are evaluated. The Skylab mobile laboratory succeeded in facilitating the data collection and sample preservation associated with the three Skylab manned flights.</p>					
17. Key Words (Suggested by Author(s)) •Medical Test Facilities •Laboratory Equipment •Portable Equipment				18. Distribution Statement STAR Subject Category: 54 (Man/System Technology and Life Support)	
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 61	
				22. Price* \$4. 25	

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SKYLAB MOBILE LABORATORY

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SUMMARY

Two primary objectives of manned space flight are to determine how well man can respond to the stresses of prolonged exposure to the space environment and to determine how well he responds to the stresses experienced upon reentry after long-term exposure to the weightless environment. The flight phase of the Skylab Program was designed to obtain the in-flight data, and the Skylab mobile laboratory was conceived as the technique to acquire postflight data on man's physiological status as soon as possible after reentry.

The Skylab mobile laboratory consisted of six basic laboratory units to conduct medical and scientific experiments and tests, a utility package to provide all utilities required by the individual laboratories, and two shipping containers to house all maintenance items and replaceable parts and to provide a workspace to perform field maintenance. The medical and scientific experimentation and testing performed within the Skylab mobile laboratory consisted of the Skylab cardiovascular, metabolic, mineral balance, and hematology experiments; microbiological operations; and physical examinations.

The Skylab mobile laboratory was used to collect required data on the crewmen during the 30-day period preceding lift-off, immediately after recovery (while the crewmen were still on the recovery ship), and after flight until the preflight baselines were reattained. The Skylab mobile laboratory enabled scientists to acquire significantly more data than they had ever been able to acquire in recovery operations before the Skylab Program. No data were lost during any of the data collection activities conducted in the recovery area. The total data collected before and after flight exceeded 99 percent of the requirements.

Because of the success of all Skylab support activities conducted with the Skylab mobile laboratory and because of the acceptance of these facilities by the scientists who used them, it is concluded that all objectives of the Skylab mobile laboratory were satisfactorily met.

INTRODUCTION

Two of the primary objectives of the Skylab Program were to determine how well man would respond to the physiological stresses of prolonged exposure to space and to determine how well man would react to the stresses encountered after reentry into normal gravity after exposure to the weightless environment for extended periods of time. In the space flights preceding Skylab, the crewmen did experience physiological changes. These changes appeared to be transitory in nature; and, in a relatively short period of time, the crewmen regained preflight baseline medical status.

In the pre-Skylab missions, however, the protocol associated with in-flight medical data gathering was somewhat limited because of the nature of the flights themselves and the priorities assigned to the in-flight activities. As a result, the effect of exposure to space was determined primarily on the basis of the difference between the baseline data taken before and after each flight.

This approach provided a wealth of medical information, but it was hampered somewhat because few in-flight measurements were taken; postflight measurements were not taken until after the crewmen had been under the influence of a gravitational environment for 2 hours or more, and the measurements were accomplished in whatever space was available on board the

*Martin Marietta Corporation.

recovery ship. Therefore, when biological changes occurred, questions still existed concerning the true in-flight extent of the change and what postflight factors, if any, reduced the extent of the change.

The Skylab experiment protocol, in which in-flight medical measurements were routinely required, was expected to answer questions concerning in-flight change. With in-flight measurements, extrapolation would no longer be necessary to explain the shape of the curve between preflight and postflight measurements. However, these data would not answer the question of how reexposure to Earth gravity influences the shape of the curve. To determine this influence, it was necessary to provide a capability for measuring a crewman's physiological status as soon as possible after recovery (in the same manner and to the same degree as preflight and in-flight measurements). The Skylab mobile laboratory (SML) was conceived as the technique and operational concept to provide this capability.

As an aid to the reader, where necessary the original units of measure have been converted to the equivalent value in the *Système International d'Unités* (SI). The SI units are written first, and the original units are written parenthetically thereafter.

PROGRAM OBJECTIVES

The primary objectives of the SML units (developed at the NASA Lyndon B. Johnson Space Center (JSC)) were to provide the capability to conduct, as soon as possible, all postflight Skylab medical experiments that must be accomplished in the recovery area, and to provide the capability to conduct general postflight physical examinations of the returning crewmen.

The secondary objectives of the SML were to provide (1) first-level medical treatment as required for the crewmen, (2) the required storage facilities at the recovery area for medical samples returned from the Skylab and command module and collected at the recovery area, and (3) a storage area for support equipment used in conducting additional postflight activities and for those experiments not performed in the SML.

A selected set of objectives, if succinct, is adequate to direct a given program. However, a more specific statement of requirements is necessary to define the final shape taken by the program. The most significant specific requirements for the SML were as follows.

1. The SML must be capable of supporting both a primary and a secondary recovery; hence, the laboratory must be portable to be used on the primary recovery ship and on an aircraft.

2. The SML must be capable of receiving the crewmen within 1 hour after splashdown and of supporting experiments and physical examinations through 3 days after recovery while at the recovery site.

3. Support of a recovery due to premature mission termination (secondary recovery) must be accomplished by the SML with as little as 24 hours notice.

4. Whenever possible, off-the-shelf equipment that requires minimum special design shall be used in the SML.

5. The data collected during preflight and postflight data-collection phases shall be of the same nature, format, and quality as that collected for those same experiments as part of the in-flight operations.

6. The SML shall provide a capability to acquire data in the areas of microbiology and general physical examinations and in support of the blood, cardiovascular, metabolic, and mineral balance experiments.

CONCEPT DEVELOPMENT

Studies and analyses were initiated to define the most feasible approach to developing the SML system. Various combinations of standard commercial semitrailers and standard expandable transportable shelters, similar to those commonly used by the U.S. Army as field hospitals, were considered in the initial planning of the SML. In December 1970, the choices had been reduced to the three best suited to satisfy the basic requirements and from which a selection could be made:

1. One trailer to house the equipment associated with the in-flight experiments (cardiovascular, metabolic, and mineral balance) and three expandable field units to house the equipment needed for the blood, microbiology, and physical examination activities.

2. Two trailers to house all the required equipment: one for housing the blood, microbiology, and mineral balance equipment; the other for housing the cardiovascular, metabolic, and physical examination equipment.

3. Four expandable field units to house all the required equipment: one housing microbiology and physical examination equipment, one the mineral balance equipment, one the blood studies equipment, and one the cardiovascular and metabolic experiments equipment.

Based on factors such as cost, amount of shelter design and development required, utility and flexibility of space, air transportability (number of aircraft required to transport the unit), and general flexibility, the concept using only the expandable field units was selected as the baseline system for the SML. Authorization was then given to develop detailed design requirements and operational concepts. Detailed equipment requirements were then requested of all principal investigators and scientists associated with each of the experimental and operational activity areas. Acquisition of expandable field units from the U.S. Army was initiated, a detailed cost study was undertaken, and action was instituted to develop a full-scale mockup of the interior layout of each shelter. The baseline concept initially selected was modified and a final SML concept was firmly established as a result of the studies and analyses associated with the equipment requirements, the understanding gained by the use of the three-dimensional full-scale mockup (fig. 1), and analyses associated with clarifying

recovery-support concepts. This baseline SML system consisted of six laboratory units, a utility package, and two shipping containers (fig. 2). The laboratory units consisted of U.S. Army expandable field units or shelters that are always used in the expanded or open configuration. These units are transportable by air in the open configuration using the U.S. Air Force C5A aircraft. The following items comprised the SML.

1. Basic laboratory unit
2. Blood laboratory
3. Cardiovascular laboratory
4. Metabolic laboratory
5. Microbiology laboratory
6. Nutrition and endocrinology laboratory
7. Operational medicine laboratory
8. Utility package
9. Two shipping containers



Figure 1.- Interior of blood laboratory with full-scale mockups installed.

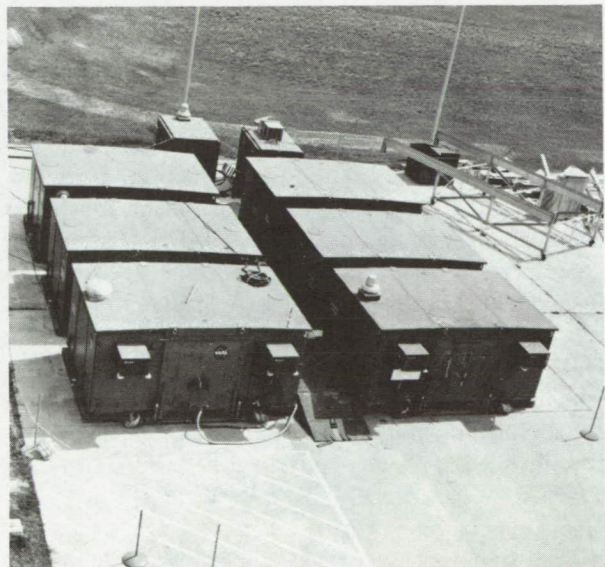


Figure 2.- Overview of the SML (one shipping container is not shown).

The experiments supported by the blood laboratory were the cytogenetic studies of blood (M111), human immunity to in vitro aspects (M112), blood volume and red cell lifespan (M113), red blood metabolism (M114), and special hematologic effects (M115). The requirements for these experiments are defined in "Experiments Study and Analysis Report, Blood Sample Handling Requirements, Phase III, Final Report."

Experiments supported by the cardiovascular laboratory included the lower-body negative-pressure (LBNP) experiment (M092) and the vectorcardiogram (VCG) experiment (M093). The requirements for these experiments are defined in two issues of the Experiment Requirements Document.

The experiments supported by the metabolic laboratory concerned metabolic activity (M171) and VCG. The procedures according to mode A in-flight protocol, as specified in "Experiments Requirements Document for Metabolic Activity," were conducted together with cardiac output and pulmonary function tests. The requirements for the VCG experiment are defined in the Experiment Requirements Document.

The microbiology laboratory supported the collection of microbiological samples and provided for immediate postflight processing of Skylab in-flight illness-event specimens and environmental and crew samples.

Experiments supported by the nutrition and endocrinology laboratory included mineral balance (M071), bioassay of body fluids (M073), and bone mineral measurements (M078). The requirements for the mineral balance and body fluids experiment are defined in "Experiment Study and Analysis Report, Mineral and Endocrinological Pool Crew and Experiment Operation Requirements"; those for the bone mineral measurement experiment are defined in "Experiment Requirements Document for Bone Mineral Measurement."

The operational medicine laboratory supported the general physical examinations of the crewmen, including the audiometric and visual examinations. The laboratory also provided limited personal hygiene facilities for crew use only.

The utility package, when supplied with site utilities (water and electricity), provided all utilities required by the six laboratories. These included power, hot and cold potable water, waste-water disposal, and vacuum. The

utility package was a modified U.S. Army "type-2, reusable transporter metal shipping box" known as a Conex box. The shipping containers were modified Conex boxes. These containers housed all maintenance items and replaceable parts needed to keep the basic units operational. They also provided space to perform field maintenance operations.

PROGRAM MANAGEMENT

The SML activities were managed through an established management team consisting of personnel from the Life Sciences Directorate (LSD), the Flight Operations Directorate (FOD), and the Center Operations Directorate (COD). At weekly coordination meetings chaired by LSD personnel, specifications were assigned, status was monitored, and problems were resolved.

The responsibilities of the LSD were as follows.

1. Designing requirements for the interiors of laboratory units
2. Identifying and procuring all equipment
3. Defining required protocols and preparing the operating procedures
4. Preparing and maintaining layout requirements and performing established reviews
5. Scheduling overall programs
6. Managing configuration

The following responsibilities were assigned to the FOD.

1. Designing requirements for the exterior of laboratory units
2. Defining and providing logistics equipment
3. Organizing interfaces with ship, aircraft, island site, and transportation and handling personnel

Personnel from the COD were responsible for the following.

1. Detail designing

2. Fabricating equipment
3. Installing equipment
4. Documenting overall facility maintenance
5. Performing test and checkout support

HARDWARE DESCRIPTION

BASIC UNIT

Each of the six basic SML units was a modified U.S. Army expandable shelter known as the "medical unit self-contained, transportable (MUST)." The MUST is an expandable structure (constructed of aluminum-faced, foam-filled honeycomb panels) and includes embedded inserts for mounting of equipment.

In the retracted configuration (fig. 3), the MUST measures 2.34 by 3.93 by 2.44 meters in height (7.66 by 12.90 by 8 feet). When expanded (fig. 4), the external dimensions are 3.93 by 5.87 by 2.44 meters in height (12.90 by 19.25 by 8 feet). The internal dimensions are 3.57 by 5.45 by 2.21 meters in height (11.71 by 17.90 by 7.25 feet).

Baseline Configuration

As provided by the U.S. Army, each shelter is equipped with electrical, water, and vacuum connectors; a sump installation; a power distribution panel; a circuit breaker panel; electrical convenience receptacles; and fluorescent light assemblies. The connectors are located on each end of the fixed center section of the shelter as an input and an output capability, thus allowing inter-connection of multiple shelters (fig. 5).



Figure 3.- The MUST's in the retracted configuration.

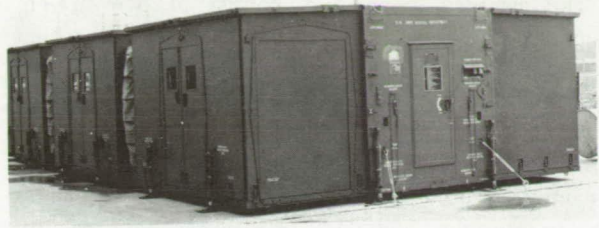
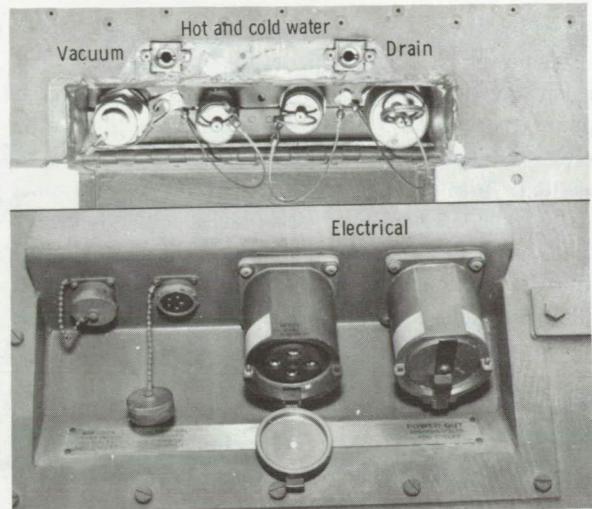
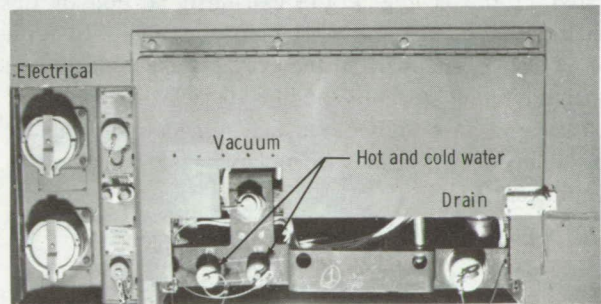


Figure 4.- The MUST's in the expanded configuration.



(a) Output side.



(b) Input side.

Figure 5.- Connector panels.

The electrical connectors consist of two five-pin snap-lock receptacles with hinged protective covers that provide for connection of a source of 120/208 volts 400 hertz and 120/240 volts 60 hertz to the unit electrical system. The water capability consists of capped, self-sealing, quick-connect/quick-disconnect connectors for inputting potable hot and cold water into the shelter and for returning the drain water. The vacuum capability is provided by a single-threaded vacuum connection to optimize the integrity of the vacuum-connection seal. The sump installation is a 400-hertz system secured to the floor of the shelter that contains connections for the sump vent, the service equipment drain, and the sump drain.

The power distribution panel that houses the circuit breaker panel and the appropriate circuit breakers is mounted near the top of the fixed center section of the shelter. A hinged door on the panel provides access to the circuit breakers and to the various wiring terminal boards. The convenience receptacles consist of 12 duplex outlets that are located at intervals along the left and right walls and on the left and right sides of the ceiling, providing 120 volts, 60 hertz, and 400 hertz electrical power.

The fluorescent light capability is provided by two assemblies in the center section ceiling and by two assemblies in each of the foldout sections. Each light assembly is flush mounted and replaceable, housing one 80-watt 400-hertz fluorescent lamp assembly. Two light switches are provided to control the lighting for both the fixed and foldout areas of the shelter.

Each shelter has two double doors and a hatch located in the ceiling of the expanded portion of the shelter. In addition, the shelters are equipped with ground lugs, tiedowns, lifting eyes, stabilizing jack pads with a leveling capability, and lifting jacks that allow the closed unit to be raised and that provide a drive-under capability by various handling and transporting equipment.

The SML Configuration

To meet the operational and use requirements established for the SML (particularly the requirements for using the expanded configuration at all times and for using standard, commercial off-the-shelf equipment whenever possible), certain modifications and/or equipment additions to the basic shelter configuration were required.

The prime modification to the MUST's was the installation of a support pallet attached to the base of the shelter in the expanded configuration. This support pallet (fig. 6) provided

1. Structural support to the unit to satisfy all operational requirements and to avoid possible problems incurred from transportation
2. Structural support to the unit and the lifting eyes to permit four-point hoisting of the expanded and fully equipped unit
3. Required interface between the unit and any loading/unloading equipment and the tiedowns needed for the interface between the unit and the recovery ship, the ground transport units, the C5A aircraft, and the hardstand at JSC
4. Required structure and hardware to permit skidding and/or towing of the unit (In this area, the existing eight lifting jacks were blocked off and four new lifting jacks were incorporated as part of the pallet.)
5. Storage trays for the interconnecting power cables and the various water and vacuum hoses
6. Pass-throughs or cable troughs to allow passage of the cables for unit interconnection

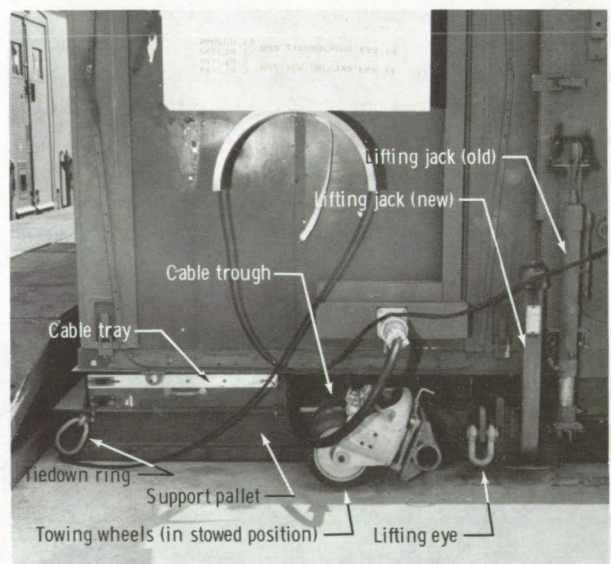


Figure 6.- Support pallet with handling provisions.

Other modifications and/or equipment additions to the basic unit consisted of those that were applied generally "across the board" to all units and those that were peculiar to a given laboratory.

Modifications that applied to all units consisted of routing cable conduits throughout the unit interior to provide the desired 60-hertz power that would be used throughout the system at the appropriate locations. This involved changing the lighting system by mounting larger 60-hertz ballasts external to each of the flush-mounted ceiling light fixtures, removing the 400-hertz sump installations and installing 60-hertz systems, and placing 60-hertz convenience outlets throughout the unit interior.

Other across-the-board changes included mounting cable hangers on the outside wall of each unit to support the interconnecting power cables during transit; mounting two commercial window-type air-conditioning units through the sidewall of the expanded portion of each unit (fig. 7); providing each unit with door locks, storage cabinets (with appropriate packing material to provide the protection necessary for the transportation environments anticipated), sinks and towel dispensers, clocks,

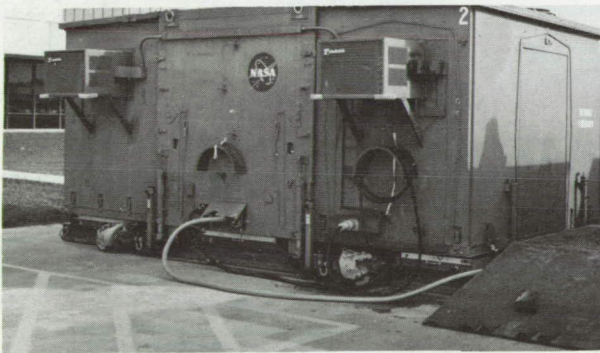


Figure 7.- The MUST with air-conditioning units and cable hangers mounted.

chairs and associated tiedowns (which consisted of eyebolts and bungee cords), emergency lights, fire extinguishers, first aid kits, clothes hangers, carpeting, intercom system, and fire-detection system.

Those changes applied selectively to a given unit consisted of the following.

1. A connector panel was installed above the entry doors of both the cardiovascular laboratories to allow interconnection of the prime data acquisition system (DAS) equipment located in each unit.

2. An electrical connector was installed through the sidewall of the cardiovascular laboratory for receipt of dedicated power for the primary DAS from the utility package.

3. The power distribution and circuit breaker panel was relocated to the opposite wall in the microbiology laboratory to allow ready access. (Access in the baseline location was blocked by the placement of the refrigerator/incubators in the laboratory.)

4. An exhaust fan was placed in the roof and a drain was placed in the floor of the microbiology laboratory to support operation of the autoclave.

5. An exhaust fan was placed in the sidewall of the nutrition and endocrinology laboratory to support operation of the fecal handling station.

6. An exhaust vent was placed in the roof of the metabolic laboratory to control odors in that laboratory.

7. The vacuum inlet connector on the metabolic laboratory was changed to a larger size to accommodate the vacuum line required to support the metabolic experiment.

8. A cable hanger was mounted horizontally on the roof of the metabolic laboratory to restrain the primary DAS interconnecting cables when the system was in transit. Restraints also were mounted on the roof to support the four-piece vacuum line used to interconnect the metabolic laboratory to the utility package.

CARDIOVASCULAR LABORATORY

Objective

The cardiovascular laboratory provided a facility for collecting all postflight data germane to the LBNP and the VCG experiments, in accordance with the protocols established and approved for those experiments. Pre-flight data were also collected as required during the 30-day period preceding launch. The operational configuration of the cardiovascular laboratory is shown in figure 8.

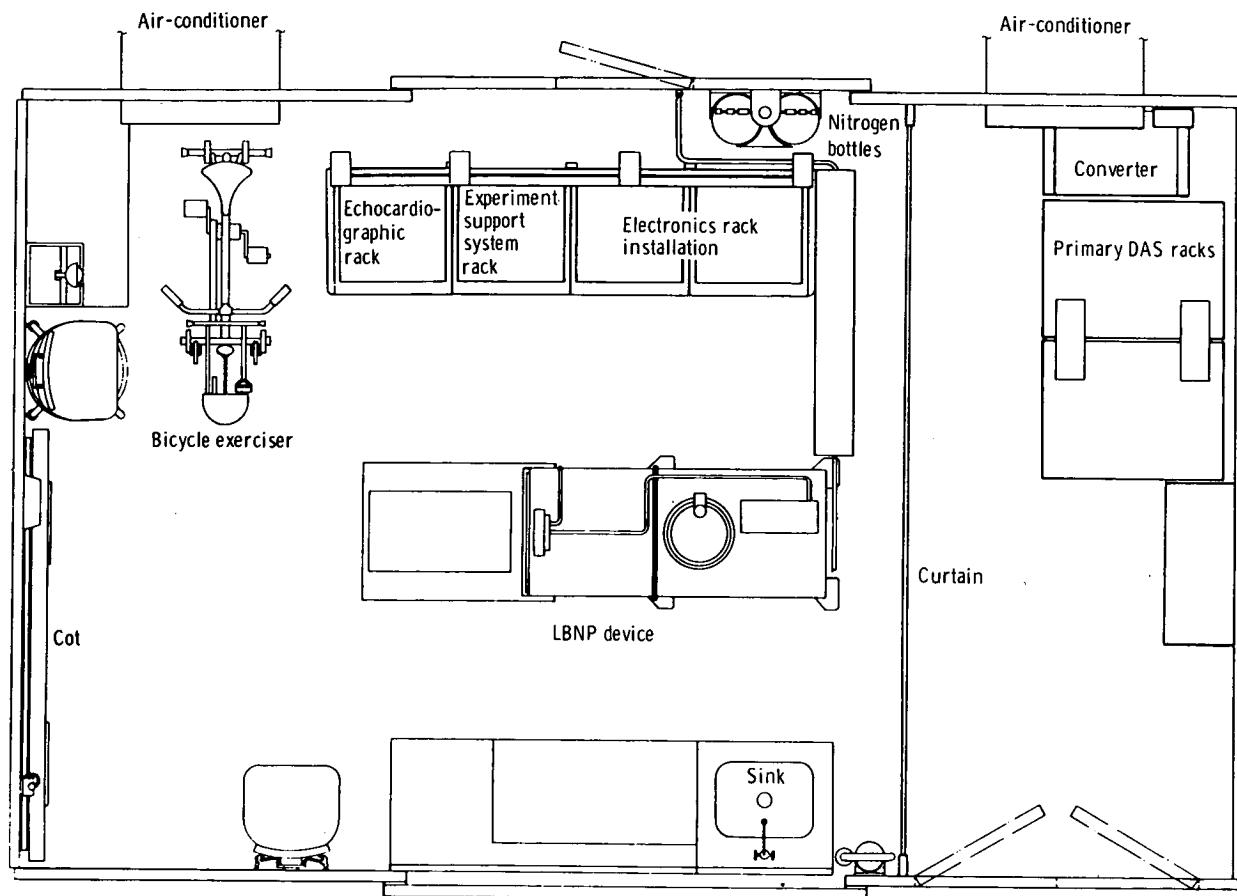


Figure 8.- Operational configuration of the SML cardiovascular laboratory.

The LBNP experiment supplied baseline information on cardiovascular responses to periodic orthostatic stress for correlation with flight data and helped predict the degree of expected orthostatic intolerance. The VCG experiment was a special type of electrocardiogram by which electrode lead placement portrayed the electrical activity of the heart along three orthogonal axes and had the advantage of permitting quantitative analysis.

Equipment

The LBNP (M092) experiment. The LBNP equipment in the cardiovascular laboratory consisted of an LBNP device and additional hardware for obtaining vectorcardiograms and measurements of leg volume changes, blood pressure, and body temperature. An experiment support system (ESS) included the various

equipment control and display systems as well as the power supply. Primary and secondary data acquisition systems were also included. A functional representation of the equipment interface is shown in figure 9.

The LBNP device (fig. 10) was a cylindrical canister of anodized metal 132.1 centimeters (52 inches) in length and 53.3 centimeters (21 inches) in diameter and was mounted directly on the floor in the center of the unit. The canister was composed of two sections that were separated for application of the leg plethysmographs. An upper torso support device, which provided support for the subject's back during one-g testing, was attached to the movable section of the canister. Pressure was reduced below ambient by a vacuum pump located in the utility package.

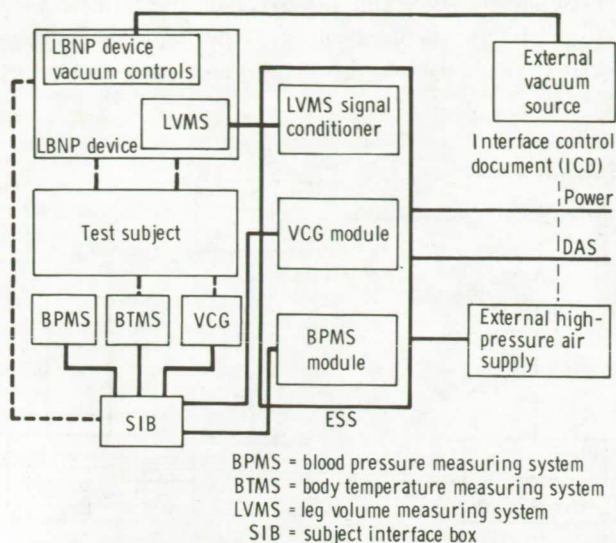


Figure 9.- Schematic of the M092 experiment interface.

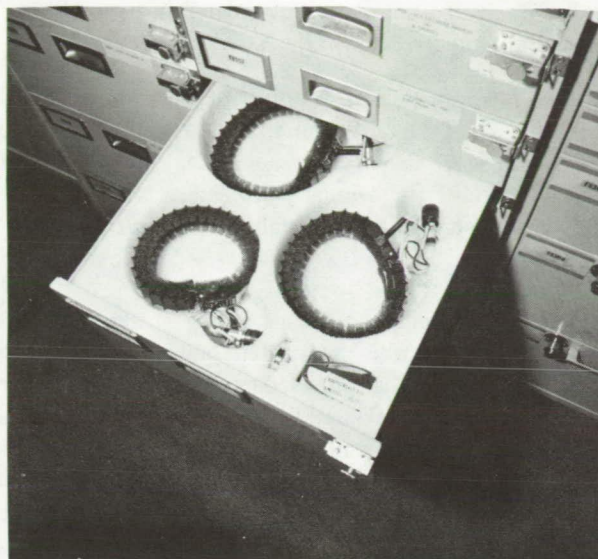


Figure 11.- The M092 legbands.



Figure 10.- The M092 LBNP device and associated hardware.

a reference adapter, provided data relative to the absolute volume changes in the calf of the subject before, during, and after the application of negative pressure. These items were stored in one of the standard cabinet drawers installed in the cardiovascular laboratory (fig. 11).

An LVMS signal conditioner, which conditioned the legband electrical signals for display on the ESS and the DAS, and an LVMS display panel, which provided displays of leg volume changes as well as controls for nulling and calibrating the legband electrical signals, were also included as integral parts of the ESS.

The blood pressure measuring system (BPMS) consisted of an arm-cuff pressurization apparatus with a pressure sensor that fitted on the crewman's left arm and connected to the ESS through a subject interface box (SIB) mounted on the LBNP device during LBNP operations. The BPMS also consisted of the SIB that contained the BPMS cuff electrical connector and the BPMS gas umbilical with an aneroid gage; a gas umbilical that provided nitrogen gas from the ESS to the SIB/cuff-hose interface; a BPMS panel that provided displays, controlled cuff cycling, and computed the systolic and diastolic pressure from the cuff-sensor signals; two standard high-pressure bottles that provided nitrogen gas to the ESS for subsequent pressurization of the BPMS cuff; and

The leg volume measuring system (LVMS) included two plethysmographs (or legbands) that, when used with

other items that are discussed in detail in the section of this report concerned with the VCG.

The nitrogen bottles were mounted to the floor and the sidewall of the unit behind the racks that housed the secondary DAS; the BPMS panel was an integral part of the ESS; and the remaining equipment was stored in the standard cabinet drawers installed in the cardiovascular laboratory.

The body temperature measuring system (BTMS) consisted of a probe used as an oral thermometer; a signal conditioner that provided excitation voltage to the probe, transmitted signals from the probe, and had a calibration capability; and a readout display. The readout display was an integral part of the ESS; the signal conditioner was an integral part of the SIB; and the probe was stored in one of the standard cabinet drawers installed in the cardiovascular laboratory.

The equipment associated with the acquisition of VCG information during the LBNP experiment is discussed in detail in the VCG equipment section. The data acquisition systems are discussed separately because of their overall importance to the SML and their interaction with multiple experiments and multiple laboratories.

The VCG (M093) experiment.- The VCG equipment in the cardiovascular laboratory consisted of five basic items, four of which pertained to the VCG recording system and included the electronics module, the SIB, the umbilical, and the electrode kit. The fifth item was a bicycle ergometer exercise device. A functional representation of the equipment interface is shown in figure 12.

The electronics module, which was an integral part of the same ESS used in the LBNP experiment, provided controls and displays for VCG operation, computed heart rate, conditioned the seven analog signals to the three VCG channels, and provided a calibration capability and a system for checking impedance.

The VCG electrode kit (fig. 13) consisted of cabling with seven electrodes and a ground electrode that sensed electrocardiographic potentials on the body surface and transmitted them to the ESS through the SIB. The kit also contained electrolyte-saturated sponges, electrode adhesive tapes to attach the electrodes to the skin, and wet wipes for cleaning the skin before and after each run. The VCG umbilical provided the electrical wiring

between the ESS and the SIB. All these items were stored in the standard cabinet drawers installed in the cardiovascular laboratory.

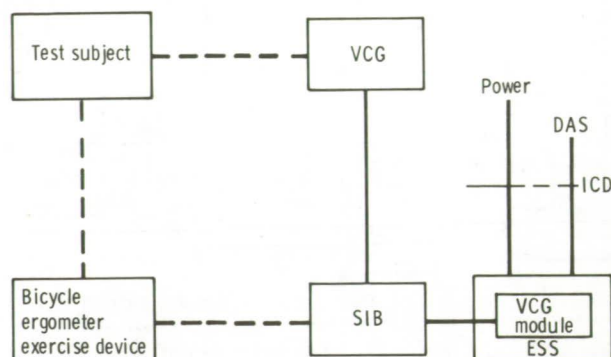


Figure 12.- Schematic of M093 experiment interface.

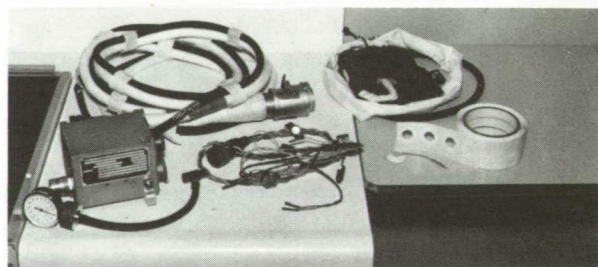


Figure 13.- The M093 VCG experiment hardware.

The SIB, which was mounted on the LBNP device during LBNP operations and handheld by the observer during VCG operations, housed the VCG electroshock protection circuitry, the preamplifiers, the signal conditioner for the BTMS, and the interconnections for the BPMS. When not in use, the SIB was stored in one of the standard cabinet drawers installed in the cardiovascular laboratory.

The bicycle ergometer (fig. 14), the exercise device used in the VCG experiment, operates like a bicycle with seat, pedals, and handlebars. This device provides a regulated exercise workload expressed in watts. (The ergometer used in the cardiovascular laboratory was not developed especially for the Skylab missions, but,

instead, was a commercial bicycle ergometer; because no attach points existed, it had to be handheld.) This ergometer was tied down to the floor of the unit while in transit but was freed for use during performance of the experiment.



Figure 14.- Commercial bicycle ergometer used in the cardiovascular laboratory.

The ESS, which supported both the LBNP and the VCG experiments, was a rack-mounted test unit in the cardiovascular laboratory and was used in conjunction with the remote status panel associated with the primary DAS (fig. 15). This system was developed for use in the Skylab Program.

Miscellaneous.- In addition to the major equipment required to conduct the LBNP and the VCG experiments, the cardiovascular laboratory housed an additional equipment item that, although not used as part of the Skylab in-flight protocol, was used to determine more detailed information on the cardiovascular system as part of the postflight data collection activities for the Skylab 4 crewmen only. This additional equipment consisted of an echocardiograph (fig. 16) that uses an ultrasonic technique to evaluate the size of the heart chamber

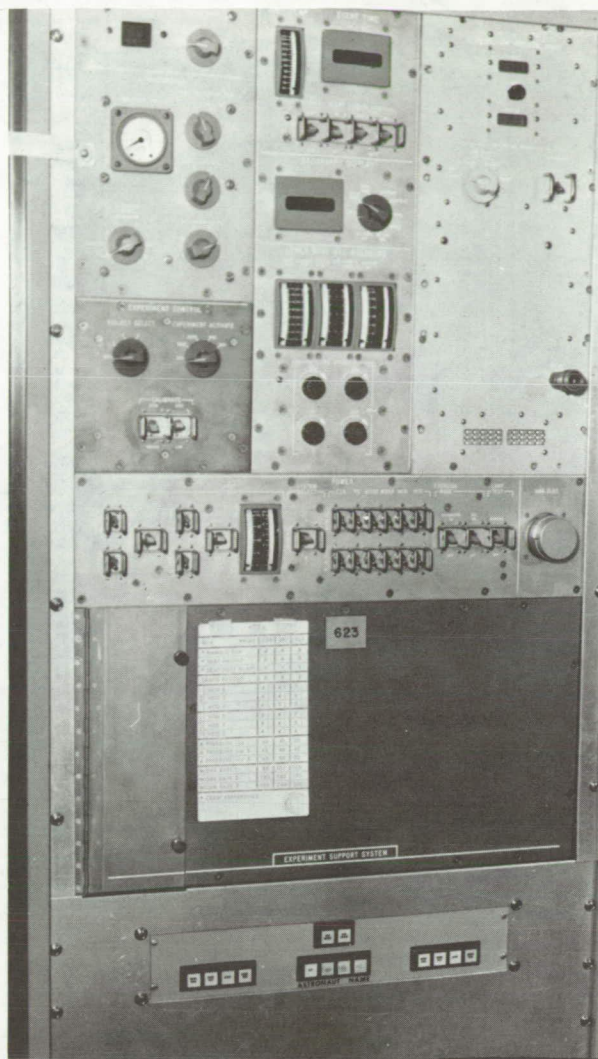


Figure 15.- The ESS.

and walls to determine whether the heart chamber and wall sizes change as a result of space flight. This equipment was added to the cardiovascular laboratory for use during the Skylab 4 recovery only and consisted of a main unit, which comprised an ultrasonic transmitter/receiver with appropriate real-time oscilloscopic monitoring displays and readout devices, a display screen, a hard copy readout device, and associated power supplies. All the echocardiograph equipment was rack mounted in a standard 48.26-centimeter (19 inch) rack adjacent to the rack in the cardiovascular laboratory that housed the ESS; the equipment was affixed to that rack by appropriate tiedowns. The rack itself was caster mounted, and

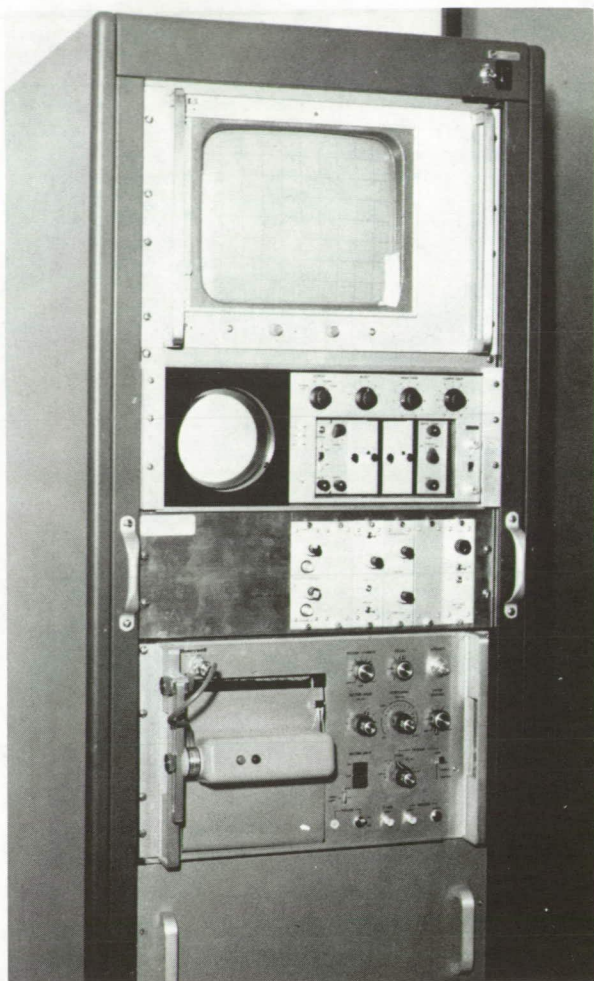


Figure 16.- Echocardiograph.

the casters were braked when the rack was located in its operational position. A cot was mounted on the wall to provide a resting facility, if needed. An electric fan was attached to the wall over the sink for use during the LBNP operations to provide cool air for the crewman.

In addition, miscellaneous equipment — consisting of manual blood pressure systems (including cuffs and stethoscopes); extra items for the LBNP and the VCG experiments (including electrode harnesses, sponges, electrolyte thermometers, waist seals, legbands, and alcohol swabs); support items for the data acquisition systems (including strip-chart recorder kits, tape recorder kits, magnetic tape, and strip-chart paper); and towels, slippers, and gym shorts for the crewmen — was

stored in the drawers of the three standard cabinets installed in the cardiovascular laboratory.

METABOLIC LABORATORY

Objective

The metabolic laboratory provided a facility for collecting all postflight data germane to the M171 metabolic activity experiment, in accordance with the protocol established and approved for that experiment. Preflight data were also collected as required during the 30-day period preceding launch.

The metabolic activity experiment provided a means of obtaining ongoing readings of the crewman's metabolic effectiveness in doing mechanical work as the mission progressed. The operational configuration of the metabolic laboratory is shown in figure 17.

Equipment

Experiment hardware.— The equipment in the metabolic laboratory consisted of hardware necessary to perform the metabolic activity experiment and certain portions of the primary and secondary data acquisition systems.

The experiment hardware consisted of a metabolic analyzer (MA) and the appropriate breathing apparatus, an ESS, an ergometer, and the ancillary equipment to measure heart rate, blood pressure, and body temperature. A functional representation of the interface between these items is given in figure 18.

The MA used a mass spectrometer to determine the partial pressure of oxygen, nitrogen, carbon dioxide, and water in the inspired and expired gases. Spirometers were used to measure separately inspired and expired breath volume. From these inputs, information was provided concerning the crewmen's respiratory function.

The MA used in the SML (fig. 19) was the Skylab qualification unit and was basically identical to the flight unit except that the mass spectrometer was configured for use in a $101.35 \times 10^3 \text{ N/m}^2$ (14.7 psi) environment rather than the $34.47 \times 10^3 \text{ N/m}^2$ (5 psi) environment used in Skylab. The MA was mounted on a rack designed to support both the MA and the ESS. The two gas bottles that provided the calibration gases to the MA

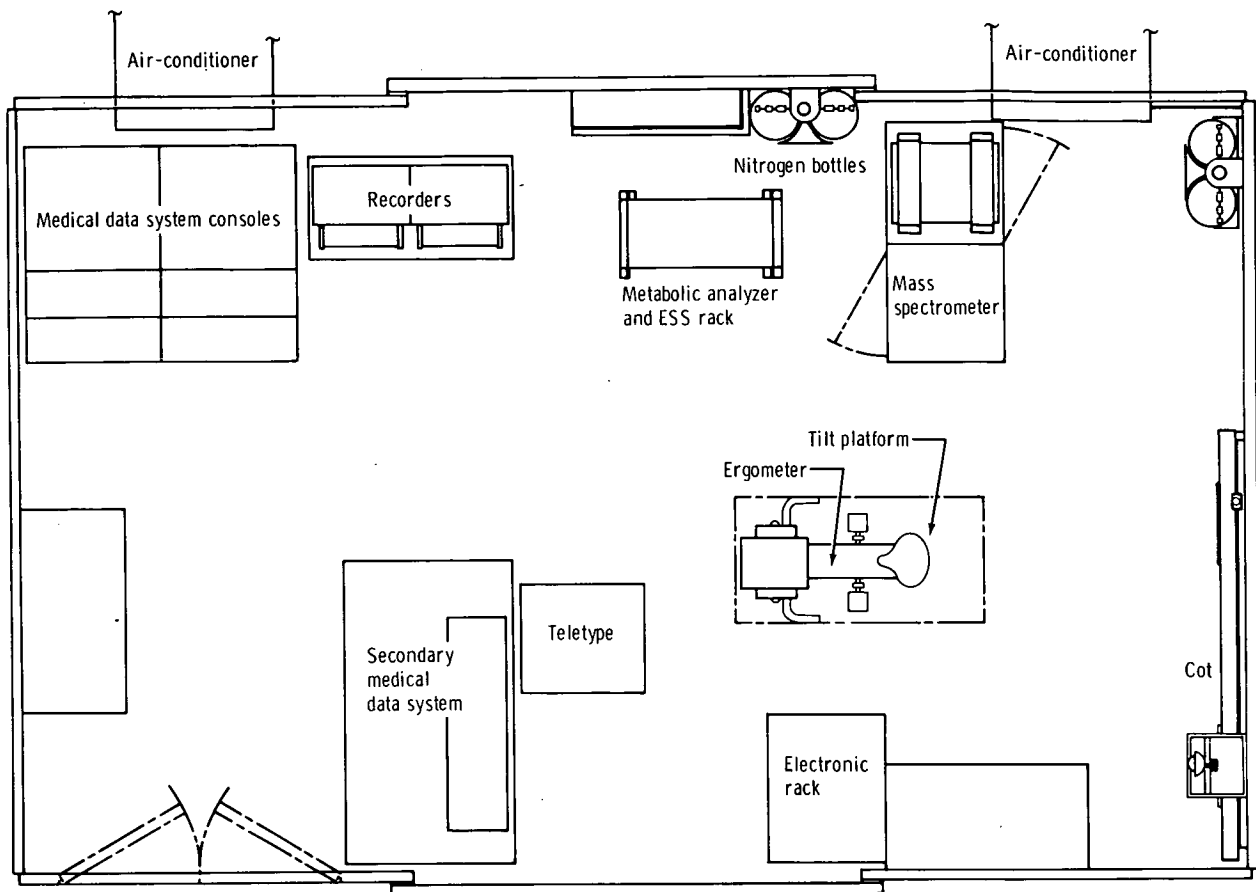


Figure 17.- Operational configuration of the SML metabolic laboratory.

were mounted to the floor and sidewall of the unit behind the MA. The ESS was also a Skylab qualification unit and included the various equipment control and display systems as well as the power supply. It was rack mounted directly above the MA.

Used in conjunction with the MA, but stored in one of the standard cabinet drawers in the metabolic laboratory, were a calibration pump, which provided variable (but known) gas volumes and concentrations to the MA for calibration, and the appropriate breathing apparatus, which consisted of nose clips, mouthpieces, check-valve assemblies, absorption cartridges, breathing hose assemblies, and spirometers (fig. 20).

The ergometer used for the metabolic experiment (fig. 21) was a Skylab qualification unit and was basically identical to the flight unit except that the mount-

ing base was modified to incorporate a hinge or pivot point along the back edge and a backrest was added. These modifications allowed tilting the total assembly backwards so that the crewmen could operate the ergometer in a partially supine position if conditions warranted doing so. The ergometer assembly was mounted directly to the floor of the unit.

The ancillary equipment used in the metabolic laboratory consisted of the VCG, BPMS, and BTMS (which were identical to those described in the section entitled "Cardiovascular Laboratory"). All items were stored in the standard cabinet drawers in the metabolic laboratory, except for the VCG electrode kit, which was stored in the cardiovascular laboratory because the crewmen initially donned the VCG in that laboratory and then entered the metabolic laboratory with the VCG electrodes attached.

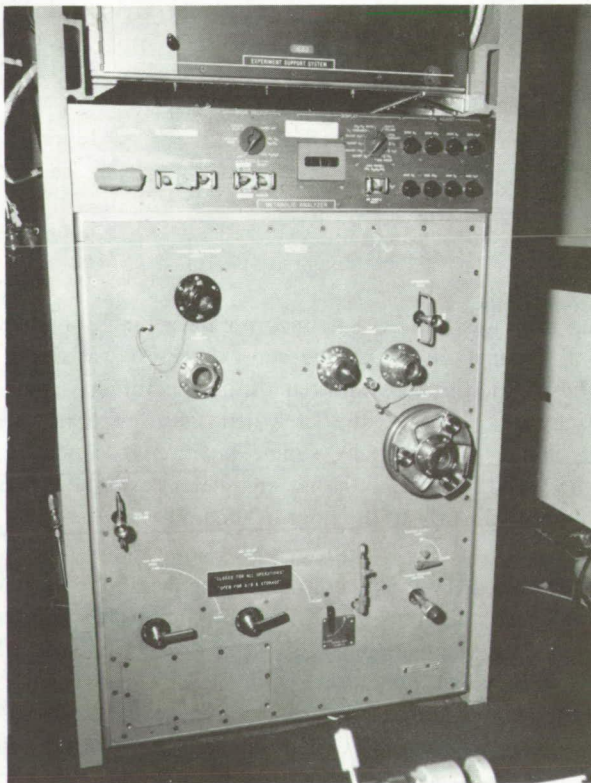
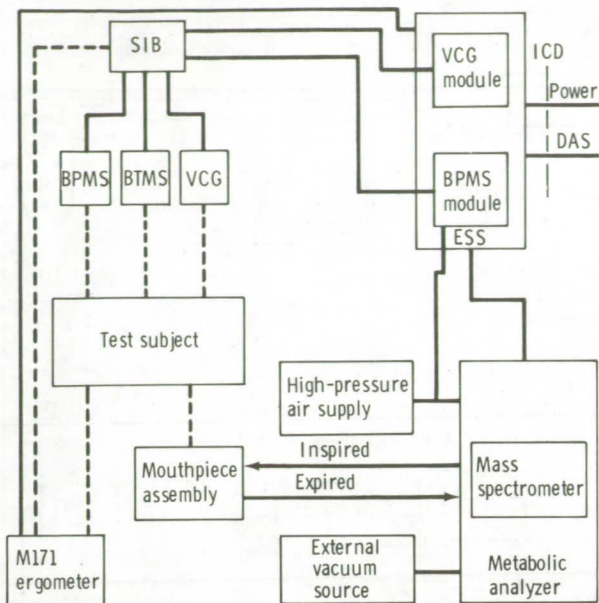


Figure 19.- The M171 metabolic analyzer.

Figure 20.- Mouthpieces, absorption cartridges, and nose clips for experiment M171.

The pressure system for the BPMS and spirometer control valves consisted of two high-pressure nitrogen bottles mounted to the floor and the associated regulators mounted to the sidewall of the unit directly behind the MA and the ESS. Pressure was reduced below ambient for the MA by the vacuum pump in the utility package.

Miscellaneous.- In addition to the major equipment items required to conduct the metabolic experiment, the metabolic laboratory housed additional equipment that, although not used as part of the Skylab in-flight operation, was necessary as part of the overall experiment support and its use in the ground-based environment. This equipment consisted of the following basic items.

1. An ergometer calibrator (consisting of a controller, computer power supply, and motor) that provided the capability to calibrate the ergometer and/or to verify

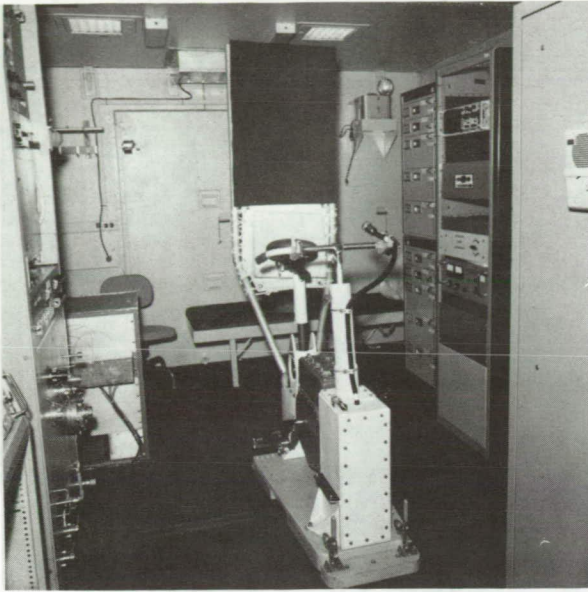


Figure 21.- Ergometer with modified baseplate and backrest used in metabolic laboratory.

its operation throughout its dynamic range. This item was mounted in one of the electronic racks in the unit. The motor was stored in one of the shipping containers.

2. A power supply that provided power to the mass spectrometer during periods in which the SML was not connected to a source of power supply. (This situation existed primarily when the SML was initially loaded onto the recovery ship and before site utilities were connected to the utility package, when the SML was in transit on the C5A, and when the SML was loaded onto the ground transportation devices to await departure at the airstrip or at the port of embarkation.) This equipment consisted of two nickel-cadmium batteries that provided 28 volts dc to the mass spectrometer, thus providing adequate power to maintain the vacuum of the mass spectrometer. These batteries and a battery charger were mounted in one of the electronic racks located in this unit. If power to the mass spectrometer was lost and the vacuum level of the mass spectrometer degraded, a roughing pump (carried in the shipping container) was available to provide a means of mass spectrometer evacuation.

3. Electronic test equipment for calibrating and supporting the operation of the primary medical equipment and the primary and secondary data acquisition systems

was located in this laboratory. This equipment was mounted on the standard electronic racks in the laboratory and consisted of such items as power supplies, oscilloscopes, digital voltmeters, calibration boxes, waveform generators, and recorders.

In addition, miscellaneous equipment was stored in the drawers of the metabolic laboratory standard cabinets. These items consisted of various handtools; cuffs and stethoscopes for taking blood pressure manually; extra metabolic experiment items such as absorption cartridges, hoses, mouthpieces, et cetera; support items for the data acquisition systems such as recorder paper, labels, pens, ink, plotter paper, and magnetic tape; exercise equipment including an upper-torso exerciser and a hand dynamometer; and various tool kits and electronic repair kits.

NUTRITION AND ENDOCRINOLOGY LABORATORY

Objective

The nutrition and endocrinology laboratory provided a facility for collecting all postflight data germane to the medical experiments on mineral balance (M071), bioassay of body fluids (M073), and bone mineral measurement (M078). Preflight data, for M078 only, were also collected as required during the 30-day period preceding lift-off. The operational configuration of the nutrition and endocrinology laboratory is shown in figure 22.

The M071 experiment was designed to obtain definitive information on mineral losses. The experiment consisted of a complete intake and output measurement on all crewmen beginning 21 days before flight through an 18-day postflight period. All nutrient and fluid intake was precisely measured; fecal, urine, and vomitus samples were collected and analyzed; measured blood samples were collected and analyzed; and body mass was measured daily.

The M073 experiment was designed to measure the biochemical changes in endocrine and metabolic physiology of the crewmen relative to fluid and electrolyte balance; regulation of calcium metabolism; adaptation to the environment; and regulation of metabolic processes. Urine samples were collected for analysis; blood samples were collected and analyzed; and body mass and fluid and nutrient intakes were measured daily.

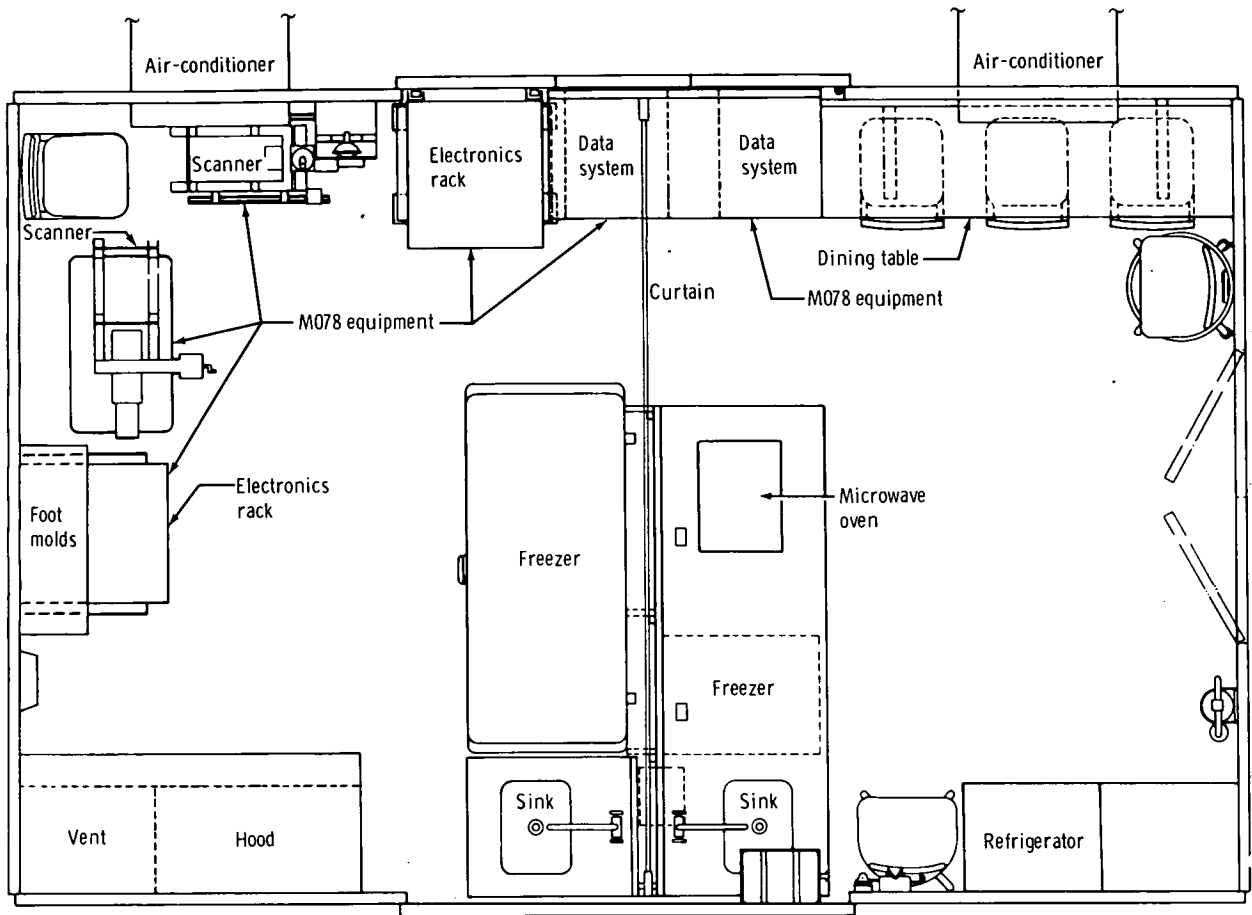


Figure 22.- Operational configuration of the SML nutrition and endocrinology laboratory.

The M078 experiment investigated the bone mineral loss associated with prolonged periods in the zero-g environment. This experiment determined, by comparing pretest and posttest measurements, the effect of weightlessness on the mineral content of the left os calcis (heel bone) and the right radius and ulna (forearm) of the crewmen.

Equipment

Mineral balance (M071). Basically, the only SML flight item needed for experiment M071 was the food that constituted the crewmen's diet during the 21-day preflight and the 18-day postflight measuring periods. This diet was configured to a 6-day repetitive cycle; therefore, only one cycle per crewman was carried aboard the SML to support recovery operations. This

method allowed recovery to occur on any day in the cycle and guaranteed maintenance of the diet for the 3 days the SML supported the crewman in the recovery area. This basic flight diet was supplemented by approved fresh foods and beverages, but only a 3-day supply was carried with the SML. The ambient food was stored in one of the standard cabinet drawers (fig. 23) installed in the nutrition and endocrinology laboratory, and the frozen food and perishables were stored in the freezer and refrigerator of the nutrition and endocrinology laboratory.

Two freezers were installed in the nutrition and endocrinology laboratory directly on the floor of the unit. One was used to store all frozen foods that were a part of the crewmen's diet, and the other was used to freeze and store excreta collected postflight and to store temporarily the returned flight specimens. A refrigerator



Figure 23.- Skylab ambient food.

was also attached directly to the floor of the unit and was used to keep perishables and to cool beverages.

A worktable with a vented hood (fig. 24) was installed along one of the sidewalls in the expandable portion of the unit to provide a work area for processing postflight excreta collections. This worktable was mounted directly above two of the standard cabinets in the nutrition and endocrinology laboratory. A balance used to obtain accurate measures of crewman excreta was used in this work area and stored in one of the drawers of the standard cabinets. Two additional worktables were also provided. One table was mounted above the food freezer, and the other (a standard cabinet) was used for meal preparation and cleanup operations. An oven was mounted directly to this table to heat the frozen foods that were part of the Skylab diet. Iodized water was also required in meal preparation and was retained in a 0.019-cubic-meter (5 gallon) container mounted directly to the worktable. The second table was used as the crew's dining table for those meals consumed in the nutrition and endocrinology laboratory.

Bioassay of body fluids (M073).- No major items of hardware were incorporated in the nutrition and endocrinology laboratory solely in support of the body fluids experiment. The equipment provided for the M071

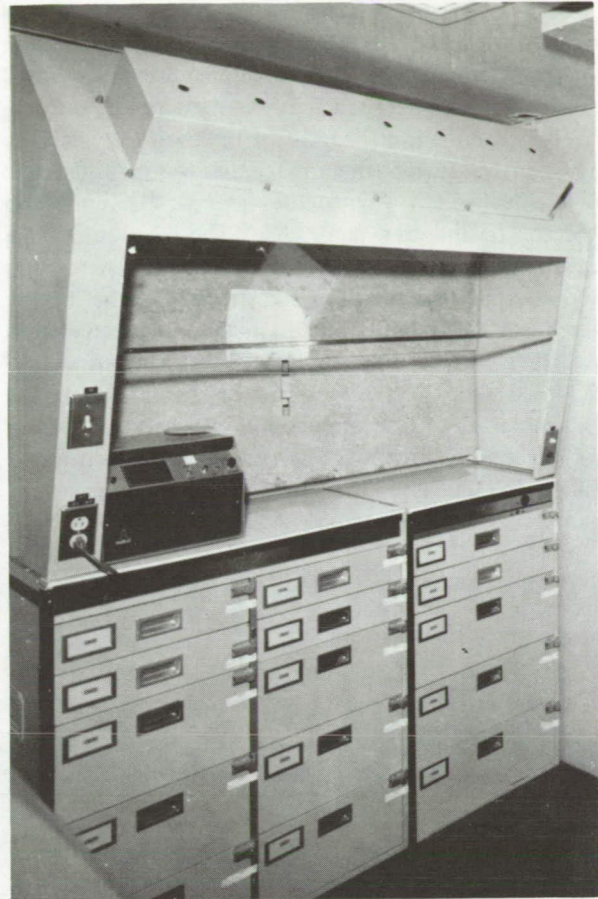


Figure 24.- Worktable and vented hood in the nutrition and endocrinology laboratory.

experiment also satisfied the basic requirements of M073. Specifically, these requirements included the food and its controlled intake, the freezer and refrigerator used to preserve the food, the sample freezer used for the freezing and retention of the urine, the iodized water used for drinking and food preparation, and the worktables used for meal preparation and consumption.

Bone mineral measurement (M078).- The bone mineral measurement unit consisted principally of a scanning yoke that held the collimated photon source and a collimated detector, an apparatus for moving the yoke, devices for positioning the limb to be scanned, and electronics associated with its operation and data collection (fig. 25).

Because measurements were taken on both the heel and the forearm, the M078 experiment hardware consisted of two sets of scanning equipment and associated electronics. The heel scanner was mounted directly to the floor of the unit in front of the chair in which the crewman was seated; the arm scanner was mounted on a table attached directly to the floor of the unit, also adjacent to the crewman's chair. The electronics were rack mounted near the respective scanners. These racks were mounted to the floor and the wall of the unit by shock isolation mounts because the electronics had been used previously during Apollo recovery operations and had used shock mounts as part of that program. The foot molds used to accurately position the subject's foot for scanning were stored in a container attached to the wall of the unit directly above the electronics rack associated with the arm scanner (fig. 25).

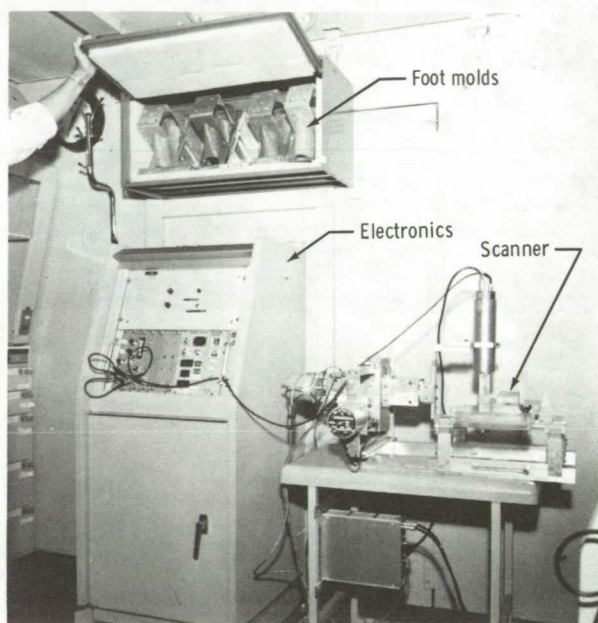


Figure 25.- Hardware for the M078 experiment.

The M078 data system consisted of a teletype (fig. 26), a tally punch, and a calculator, which were used to provide data acquisition, storage, and transfer to the computer and to perform data calculations. This equipment was mounted on one end of the worktable that the crewmen used as a dining table.

The M078 experiment operation required the portable scanner with detector, the source holder used as a transfer container for the radioactive scanning material, the bone standard used for calibration of the experiment instrumentation, and the hydroxyapatite step standard used to convert computer units to milligrams per square centimeter hydroxyapatite and to assure linearity of the scanner response to bone mineral content. These items were stored in the standard cabinet drawers in the nutrition and endocrinology laboratory.



Figure 26.- Teletype system used for the M078 experiment.

Miscellaneous.- Miscellaneous equipment items used to support the M071, M073, and M078 experiments were stored in the drawers of the six standard cabinets in the nutrition and endocrinology laboratory. These items included eating utensils, plates, napkins, and assorted glassware; beakers, cylinders, wipes, dye markers, urine and fecal collectors, colored tapes for identification marking, specimen bottles, forceps, et cetera; spare parts for the M078 experiment such as scanners, preamplifiers, single channel analyzers, rate meters, buffers, timers, and power supplies; a toolkit for maintenance of the M078 experiment and its associated data system; and support items for the M078 data system such as teleprinter paper, teletype ribbons and tape, extra teletype hubs, et cetera.

OPERATIONAL MEDICINE LABORATORY

Objective

The operational medicine laboratory provided a facility for performing the immediate postflight physical examinations. The data obtained here, together with those acquired from monitoring the results of the medical experiment activities conducted in the other laboratories, provided the medical community the information necessary to determine postflight and adaptation changes of the returning crewmen.

This laboratory also provided the facility for the immediate collection of samples required by personnel from the blood and microbiology laboratories as well as for the overall collection of urine and fecal samples as required by the nutrition and endocrinology laboratory.

It was also a rest station for the crewmen and provided them with facilities to shower, change clothing, and refresh themselves. The configuration of the operational medicine laboratory is shown in figure 27.

Equipment

There were four categories of equipment in the operational medicine laboratory: (1) equipment required to conduct a physical examination, (2) equipment required for the collecting of samples for subsequent use by other laboratories, (3) equipment used as a crewman rest station, and (4) equipment required to support medical emergencies.

Physical examination.- Standard medical kits and an examination table (fig. 28) formed the nucleus of the equipment used for the standard physical examination

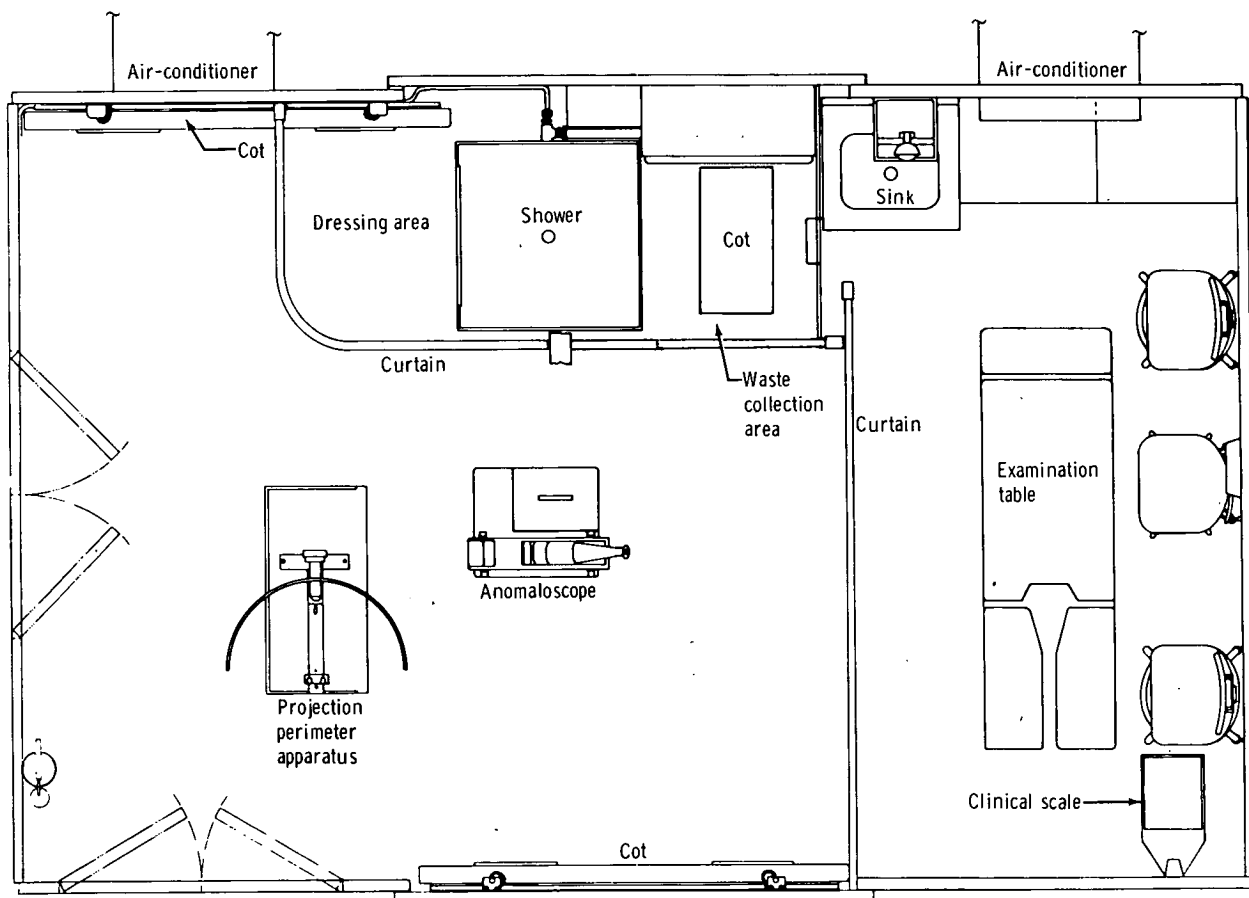


Figure 27.- Operational configuration of the SML operational medicine laboratory.

that was conducted immediately on the returning crewmen. The examination table, mounted directly to the floor of the unit, had a positioning capability to optimize the position of the crewman in relation to that of the attending physician. The physician's medical kit was stored in one of the drawers of the standard cabinets installed in the operational medicine laboratory. The medical kit contained blood pressure kit, a thermometer, a stethoscope, an ophthalmoscope-otoscope set, tongue depressors, et cetera. A clinical scale was provided to weigh each crewman. This scale was attached directly to the floor of the unit; it was fastened to the unit sidewall by bungee cords during transit and then freed during use.

Vision testing equipment consisted of apparatus for measuring depth perception, color vision, peripheral-vision fields, amplitude of accommodation and convergence, and intraocular tension. All the equipment was stored in drawers of the standard cabinets installed in the operational medicine laboratory except the anomaloscope and the projection perimeter, which were mounted on tables that were bolted directly to the floor of the unit.

Auditory testing equipment consisted of a noise analyzer that measured background noises during hearing tests and an audiometer with appropriate accessories for measuring hearing acuity. These items were used in the laboratory rather than in a special soundproof booth

external to the SML. When not in use, they were stored in the drawers of the standard cabinets in the operational medicine laboratory.

A neurological examination kit to evaluate neurological functions was also stored in one of the drawers of the standard cabinets in the operational medicine laboratory. A transmitting computer input/output device, stored on the wall in the sample-collection area during transit and assembled for operation on the examination table, was used to store or to transmit to JSC data about the entire medical protocol conducted in the recovery area.

Sample acquisition.- An area for collection of fecal and urine samples was an integral part of the operational medicine laboratory. This partitioned area adjacent to the shower had an entrance protected by an opaque curtain that could be positioned to provide complete privacy. The actual collection equipment was similar to the portable waste collection kit used by the crewmen during all other preflight and postflight monitoring periods. This equipment consisted of a portable toilet seat, waste collectors for both urine and feces, and appropriate toilet tissues (fig. 29).

Microbiology sampling required no special equipment. All swabs and tubes of media were supplied by the microbiologists and used at the tabletops provided as an integral part of the standard cabinets installed in the unit.

To collect blood samples, tables were installed in the unit to hold all the required blood-collection equipment and the scintillation detection system brought in from the blood laboratory. The scintillation detection system, which consisted of preamplifiers, analyzers, timer-scaler, rate meter, spectroscopy amplifier, and appropriate power supplies, was used to measure the radioactive content of the blood samples after isotope injection. This system was normally transported in the blood laboratory and transferred to the operational medicine laboratory as part of the deployment procedures on board the recovery ship.

Rest station.- A shower was an integral part of the rest station together with the privacy area separated by an opaque curtain where crewmen dried and dressed. Towels, soap, and washcloths were stored in one of the drawers of the standard cabinets in the operational medicine laboratory, and clean clothing was carried in personal suitcases.

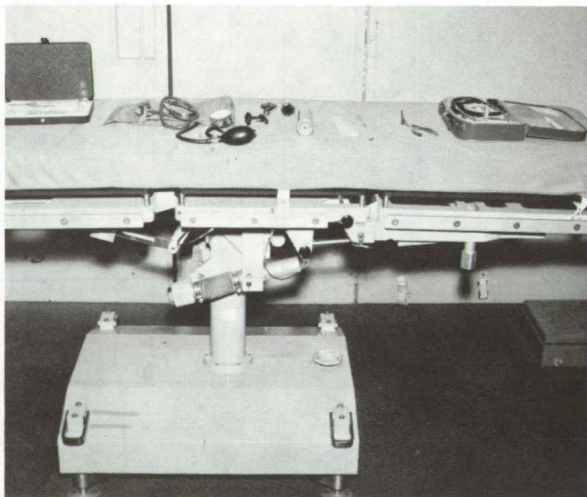


Figure 28.- Examination table and physical examination equipment.



Figure 29.- Privacy area with portable waste collection kit.

Three bunks (or cots) provided a place for the crewmen to rest. Two folddown bunks were mounted on the walls of the unit; the third bunk was a foldup rollaround type that was tied to one of the folddown bunks during transit. Linens were usually preinstalled on the bunks, and spares were carried in the drawers of the standard cabinets.

Medical emergencies.- Equipment necessary to support selected medical emergencies that the returning crewmen might encounter was part of the operational medicine laboratory. For emergencies beyond the capability of this laboratory, the medical facilities of the primary recovery ship or the base hospital were available.

The medical emergency equipment included intravenous sets, resuscitation kits, injection kits, minor and major surgery kits, emergency drug kits, catheterization kits (fig. 30), suture kits, bandage kits, syringe kits, an endotracheal tube, oxygen kits, and a defibrillator. The three oxygen kits were mounted directly to the laboratory wall; the defibrillator was attached to a roll cart



Figure 30.- Catheterization kit stored in the operational medicine laboratory.

tied to the wall; and the other items were stored in the drawers of the three standard cabinets installed in the operational medicine laboratory.

Miscellaneous.- Extra linens, soaps, toilet tissues and other wipes, notebooks, and a dirty-clothes bag were also stored in this laboratory in the drawers of the standard cabinets.

BLOOD LABORATORY

Objective

The blood laboratory was the facility in which immediate analyses on the blood drawn in the operational medicine laboratory were performed in accordance with the protocols established and approved for each experiment in the blood-study series. This laboratory was also used for preprocessing those samples returned to JSC for subsequent detailed analysis. The operational configuration of the blood laboratory is shown in figure 31.

The cytogenetic studies of the blood (M111) experiment was designed to determine whether some space-flight parameter produces cytogenetic effects in cells (effects which are observed as changes in the form of a slight increase in the number of chromosomal aberra-

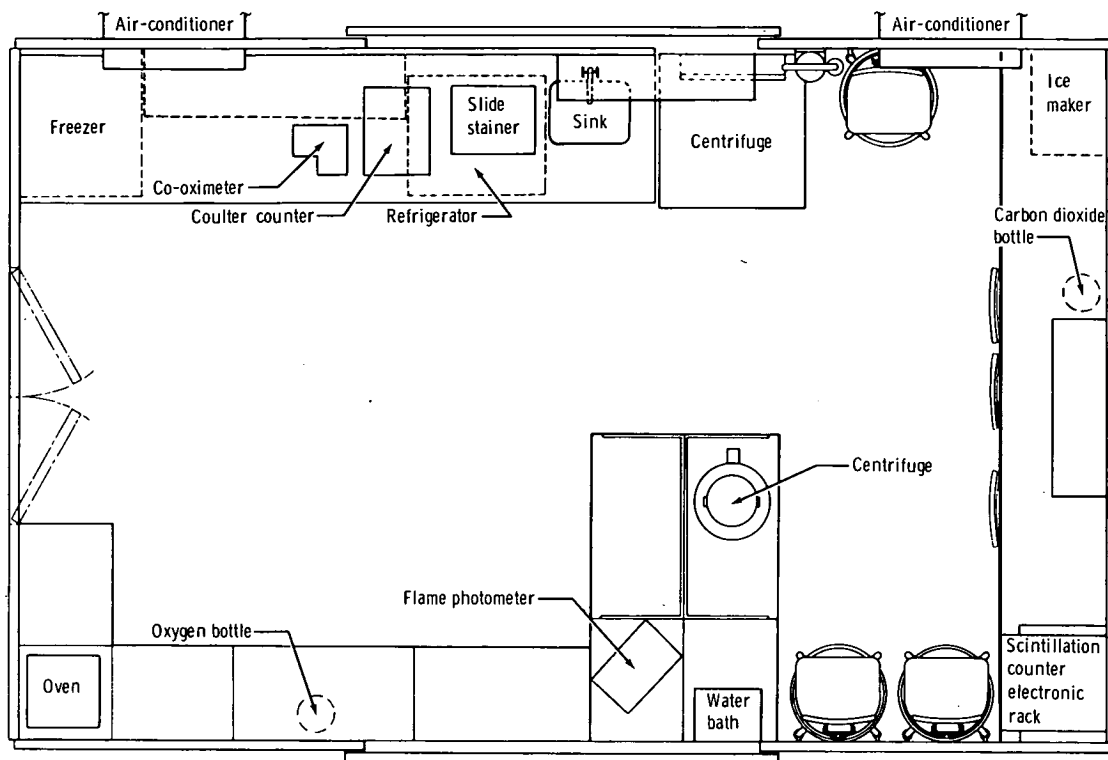


Figure 31.- Operational configuration of the SML blood laboratory.

tions in leukocyte samples). The human immunity to in vitro aspects (M112) experiment was designed to detect quantitative and qualitative changes in the immunoglobulins and related proteins and lymphocyte functions; this experiment consisted of two investigations, one dealing with humoral responses and the other with lymphocyte reactivity. The blood volume and red cell life span (M113) experiment was designed to determine red blood cell production rate, measure red blood cell mass changes and life span, determine selective age-dependent erythrocyte destruction, and determine plasma volume changes. The red blood cell metabolism (M114) experiment was designed to detect any changes that space-flight exposure might produce in the glucose metabolic pathway of the red blood cell; this experiment also investigated the chemical composition and structural integrity of the red blood cell membrane. The special hematologic effects (M115) experiment was designed to provide more extensive analyses of blood to yield a better understanding of the extent, time course, and etiology of the hematological changes noted in red cell mass, food and electrolyte balance, and other blood constituents as a result of space-flight exposure.

Equipment

The blood laboratory contained that equipment necessary to conduct the M110 series experiments; however, the samples were actually acquired in the operational medicine laboratory. The blood-sampling equipment consisted of an infusion set with a plastic syringe and a thin-walled silicone needle together with various vials and tubes containing selected anticoagulants for retaining the drawn blood. These blood-sampling kits and the retaining vials were stored in drawers in the standard cabinets in the blood laboratory.

The following equipment was installed directly on the floor of the unit or on the tabletops provided by the standard cabinets in the blood laboratory: an incubator for providing proper controlled temperature for culture development; a freezer for preserving blood samples at frozen temperatures; a refrigerator for preserving media and samples at selected temperatures; a refrigerated centrifuge for separating blood constituents under controlled cool temperatures; standard centrifuges for

separating blood constituents under ambient temperatures (fig. 32); wall-mounted lamps to provide additional lighting for examining cultures with the unaided eye; and a Coulter counter, slide stainer, microscope, flame photometer, water bath, and co-oximeter for performing selected operations and analyses on the blood samples.

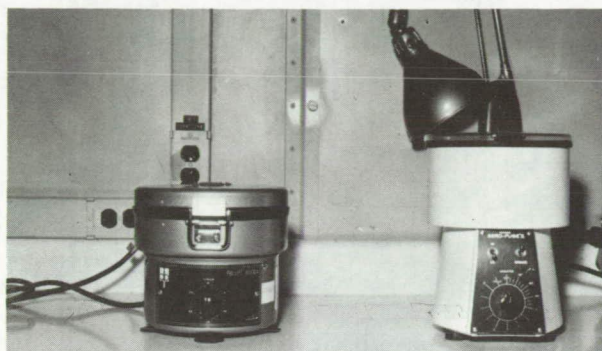


Figure 32.- Centrifuges mounted on worktable in blood laboratory.

Equipment stored in the drawers of the eight standard cabinets in the blood laboratory included centrifuges, automatic diluters, a pH meter and associated kit, differential counter, hotplate stirrer, kits for the various experiments, clinical hematology kits (fig. 33), urinalysis kits, sample-packaging and sample-preparation kits, specific-gravity kits, blood-collection kits, and vacuum container kits. Miscellaneous glassware and support equipment such as graduated cylinders, pipettes, flasks, beakers, syringes, reagent bottles, stirring bars, culture tubes, diluters, multipipettes, and test tubes (fig. 33) were also included.

MICROBIOLOGY LABORATORY

Objective

The microbiology laboratory was a facility for (1) performing time-critical processing steps and analyses of those microbiological samples obtained in flight from the Skylab environment and crew and (2) obtaining and initiating processing of postflight samples collected from the crew and the command module, in accordance with protocols established and approved for these activities.

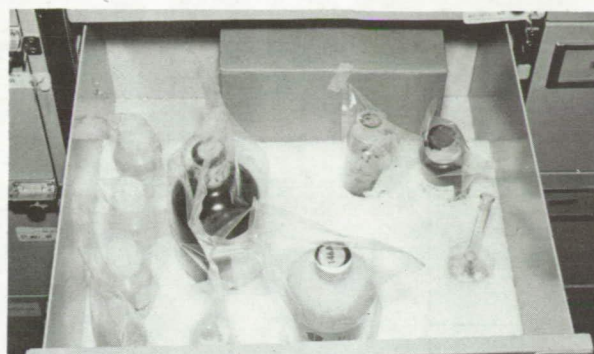


Figure 33.- Part of clinical hematology kit stored in the blood laboratory.

The microbiological experiments offered a means of determining the types and numbers of micro-organisms in the crew samples and the environmental samples returned from the orbital workshop and in the postflight samples taken from the crewmen and the command module. The operational configuration of the microbiology laboratory is shown in figure 34.

Equipment

The microbiology laboratory contained that equipment necessary to fulfill the experiment objectives, although the blood and microbiology samples were actually acquired in the operational medicine laboratory.

A repressurization system capable of repressurizing the resupply and return container with high-pressure gaseous nitrogen and consisting of the appropriate regulators, relief valves, pressure gages, and filtering system was installed under the laminar flow bench and mounted to the leg of the flow bench and the floor of the unit. Thus, the system provided a repressurization capability of the resupply and return container in the work area of the laminar flow bench (fig. 35). The laminar flow bench, or clean bench, provided a clean work area and simultaneously protected the workers from any airborne contaminants. This bench was a self-contained unit mounted directly to the laboratory floor.

Three incubators/refrigerators were mounted directly to the floor of the unit to provide a controlled temperature for the prepared media en route to the recovery area and while awaiting the samples for analysis and to provide the required controlled temperatures for the

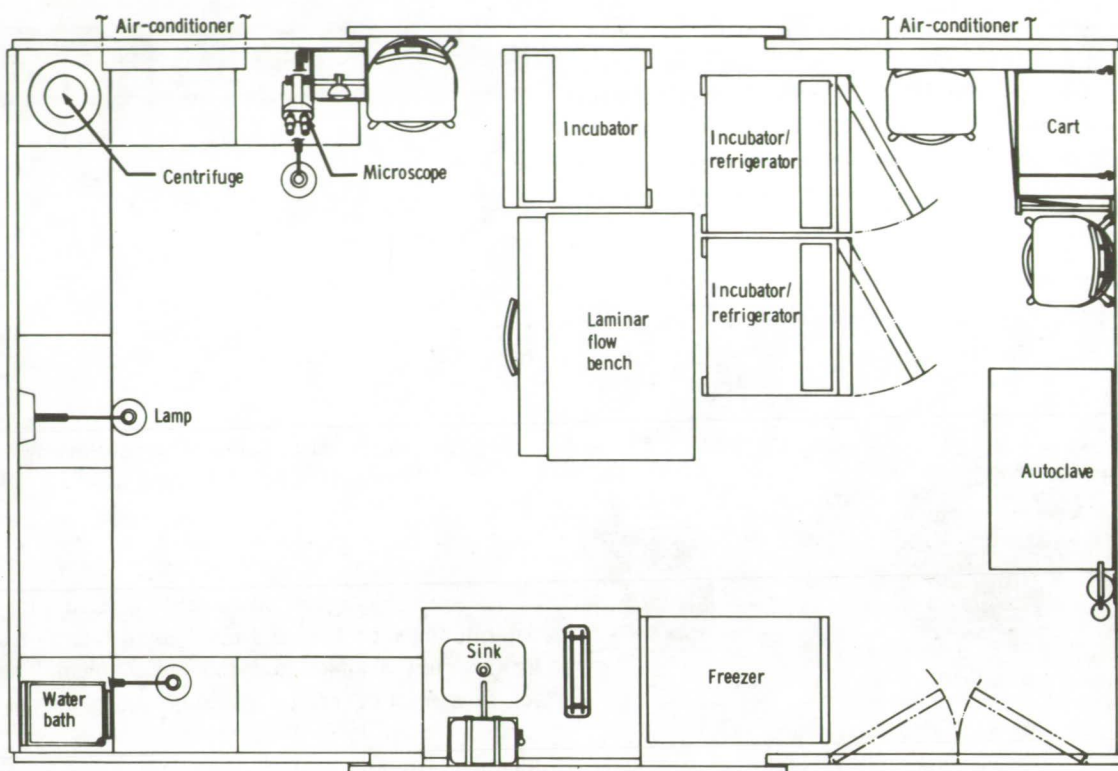


Figure 34.- Operational configuration of the SML microbiology laboratory.

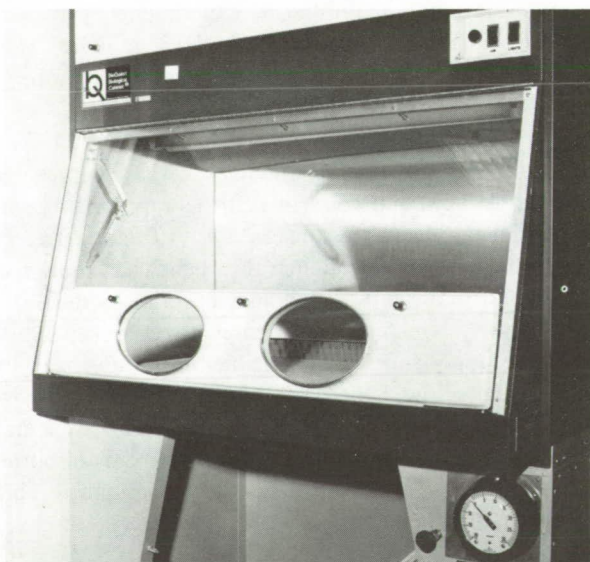


Figure 35.- Laminar flow bench with regulator for resupply and return container repressurization system.

cultures being processed. A freezer, also mounted directly to the floor, was provided to support the required virology samples.

An autoclave unit was provided to sterilize the various instruments, containers, and/or flasks solutions. This unit used distilled water provided in four 0.019-cubic-meter (5 gallon) containers mounted directly below the main body of the autoclave. An exhaust fan in the roof of the laboratory removed heat and odors, and a vent line through the floor of the unit was used to vent excess steam.

Operational equipment mounted directly to the top of the standard cabinets throughout the microbiology laboratory included a water-bath unit that provided a water source at a controlled temperature, a microscope for examining slide specimens (fig. 36), a centrifuge for separating blood constituents, and a slide-staining tray to facilitate the required slide staining.

Three wall-mounted lamps provided additional lighting to examine cultures with the unaided eye. Operational and support equipment stored in the drawers of the seven standard cabinets installed in the microbiology laboratory included a propane gas burner (and associated gas resupply bottles) used as a heat source for sterilizing handtools, such as streaking loops, and for heating media and solutions; an ice chest used as a controlled environment for transporting samples back to JSC; a balance for weighing selected items accurately; a hotplate for mixing and heating liquids; a mixer for mixing solutions in containers of various sizes and shapes; and miscellaneous glassware and support equipment (graduated cylinders, pipettes, syringes, flasks, beakers, test tubes, petri dishes, various chemicals, agars, extracts and broths, staining kits, media preparation kits, inoculation kits, filter kits, a virology sample kit, and accessories for the centrifuge (fig. 37) and microscope) required to support the microbiology analysis activities, including media preparation.

DATA ACQUISITION SYSTEMS

The SML had both a primary and a secondary data system so that a failure of one of the systems did not degrade the satisfaction of the overall objectives (i.e., data collection of selected critical parameters on the returning crewmen immediately upon return to Earth gravity). Although the systems were classified as primary and secondary, the basic operating procedure was to use both systems simultaneously at all times to preclude inadvertent loss of data if one system failed in the middle of a data run.

The primary system was a digital system patterned after the one successfully used during the baseline data collection activities of the Skylab medical experiments altitude test (SMEAT) and the one-g trainer. The secondary system was both a digital and an analog system and was similar to the systems used during Apollo recovery operations and by the scientists and principal investigators during laboratory testing of the Skylab hardware.

Primary DAS

Objective. The major purpose of the SML primary DAS was to provide the capability to acquire, record, and display postflight medical data on each crewmember during the planned postflight experiment activities relative to the Skylab major medical experiments (M092, M093, and M171). The secondary objective of this system was to collect data during the preflight and post-flight data collection activities conducted at JSC.



Figure 36.- Microscope and centrifuge mounted on tabletop in the microbiology laboratory.



Figure 37.- Accessory kit for the centrifuge stored in the microbiology laboratory.

The primary DAS was located in the cardiovascular and metabolic laboratories and had the capability of supporting both laboratories simultaneously. The DAS interfaced with these two laboratories so that each laboratory functioned as though it had a dedicated system. Each laboratory was supported with VCG strip-chart data and a digital display of all other data. The experiment operator had the capability of starting and stopping the data capture from a control panel, and the data

system computer fed back the DAS status and the operational readiness data through a status panel. The digital tapes produced were compatible with the digital tapes produced during SMEAT and one-g operations and thus could be readily processed by the data processing facility at JSC.

Special diagnostic and self-check functions were designed into the system to facilitate mean time to repair and deployment time requirements. The design criteria were to develop a system that was qualified for reliable operation in the predicted environment; hence, the overall computer consisted of the ruggedized version of the same system that was used for the SMEAT and one-g trainer operation.

Equipment.- In the cardiovascular laboratory, the equipment was contained in two standard equipment racks (fig. 38), a status panel, a connector panel, and a 400-hertz converter unit. The DAS computer rack housed the central processor unit (CPU), the memory chassis, the input/output expansion chassis, the tape recorder assembly, and the power panel.

The CPU was the main frame chassis and consisted of the 4000-word memory CPU section and an additional

4000-word memory section. The CPU contained the controls and displays required for operator communication with the computer. The memory chassis added an additional 8000-word memory to the computer.

The input/output expansion chassis added an additional 8000-word memory to the computer. It was also the interface/connecting link between the computer and the peripheral analog or digital devices and provided space for the signal conditioner, analog-to-digital (A/D) converter, A/D converter control, lamp driver, and digital-to-analog (D/A) converter circuit cards.

The magnetic tape unit was a seven-track magnetic tape recorder. The tape deck contained two 26.7-centimeter (10.5 inch) reels that were capable of holding 732 meters (2400 feet) of 1.27-centimeter (0.5 inch) computer tape.

The power panel contained the controls and displays necessary to apply power to the computer rack. One ON/OFF switch actuated a 15-ampere 400-hertz circuit breaker, and one ON/OFF switch actuated a 20-ampere 60-hertz circuit breaker. The displays showed power ON or OFF status.

The DAS control and display rack housed the strip-chart recorder, the cathode ray tube (CRT) display, the CRT controller, the keyboard, the status panel, the tape recorder assembly, and the power supply assembly.

The strip-chart recorder was a commercial panel-mounted six-channel analog recorder. A significant feature of this recorder was a pressurized inking system that produced traces that were immediately smudge-proof and uniform in width at any pen velocity. The system contained two disposable ink cartridges that were replaceable. Built-in solid-state amplifiers provided input ranges from 1 millivolt per division to 500 volts full scale. Controls, including 13-step attenuation, intermediate sensitivity, and pen positioning, were provided on the front panel for each channel. Eight chart speeds from 1 mm/min to 125 mm/sec were selected by pushbuttons.

The CRT display consisted of two 20.32-centimeter (8 inch) commercial displays mounted in a common chassis. Operator controls similar to a television set were available to control power ON/OFF, contrast, brightness, and synchronization. Data were displayed on the CRT in alphanumeric form. Data from the experiment being performed in the cardiovascular laboratory were



Figure 38.- Primary DAS equipment in the cardiovascular laboratory.

displayed on one CRT display, and data from the metabolic laboratory were displayed on the other CRT display.

The CRT controller was a commercial display generator that contained logic circuitry for controlling the display of data on the CRT displays. A power ON/OFF switch on the control panel applied and removed power to the controller.

The keyboard was a commercial unit that resembled the keyboard of an electric typewriter. In addition to the standard typewriter keys, the keyboard had cursor control keys to edit data and function keys to initiate communication with a computer or any of the peripheral devices associated with the system.

The status panel was rack mounted and contained the controls and displays available to the DAS operator. Controls for selecting record or calibration modes of operation and for selecting calibration voltage were located on the panel; ON/OFF controls provided power to the control and display rack. Indicator lights were mounted on the panel to alert the operator of errors in data input, magnetic tape, CRT display, memory, and strip-chart recorders. Indicator lights on the panel also alerted the operator of the experiment being conducted (i.e., M092, M093, or M171).

The magnetic tape unit was identical to the one located in the DAS computer rack and provided backup to the first unit, permitted an off-line decommutation of the tapes, and converted the data to the standard ground support equipment and pulse code modulation (PCM) information format for input to the JSC data processing facility.

The power supply assembly consisted of a commercial ± 15 -V dc unit and a ± 12 -V dc unit located in the back of the control and display rack. The ± 15 -V dc power supply provided power to the signal conditioner circuit boards; power to the status panels was provided by a ± 12 -V dc power supply.

The status panel was remote from the two main electronic racks of the DAS and was mounted in the cardiovascular laboratory in the same rack as the ESS. The panel contained 14 controls/displays accessible to the operator for selecting experiments, selecting subject identification, starting and stopping the data acquisition, and monitoring the DAS status. The connector panel, also remote, was mounted on the rear of the electronic

rack adjacent to the ESS rack and contained 80 coaxial connectors for patching signals to peripheral devices. The 400-hertz converter assembly was a self-contained commercial unit consisting of two converters. This assembly was located adjacent to the DAS computer rack and provided the 400-hertz power to the magnetic tape units.

In the metabolic laboratory, the equipment was contained in two lowboy consoles — the CRT display console and the strip-chart recorder console (fig. 39). The CRT display console housed a CRT display, a status panel, and a power panel.



Figure 39.- Primary DAS equipment in the metabolic laboratory.

The CRT display was a 43.2-centimeter (17 inch) commercial display unit capable of receiving experiment data converted to engineering and medical units and displaying the data in alphanumeric form. The operator controls on the display were similar to those on a standard commercial television set: ON/OFF, contrast, brightness, focus, vertical hold, horizontal hold, and height.

The status panel in the metabolic laboratory was identical to the one located in the cardiovascular laboratory, which was mounted in the same rack as the ESS. It contained controls for selecting experiments and modes of operation, subject identification, and data acquisition starts and stops. The displays monitored DAS "ready" and DAS "error" status. The power panel was a rack-mounted panel that contained the controls and displays necessary to apply power and indicate power ON/OFF status for the CRT display console.

The strip-chart recorder console housed the strip-chart recorder, the patch panel, and the power panel. The strip-chart recorder was identical to the one mounted in the control and display rack in the cardiovascular laboratory, and the patch panel was identical to the one mounted in the rear of the electronics rack in the cardiovascular laboratory. The power panel was a rack-mounted panel that contained the control for applying power to the strip-chart recorder console and an indicator displaying ON/OFF status.

Functionally, the DAS operated as shown in figure 40.

Software.— The software associated with the primary DAS consisted of a series of system and test programs structured and designed to verify correct system operation; to ensure proper data acquisition; to perform decommutation; to provide a playback capability; and to perform selective testing on the computer, its internal options, and peripherals. Basically, the test executive program was the controlling factor in the test program system. In addition to loading, executing, and monitoring the other test programs, the test executive program provided utility aids for debugging, program maintenance, and hardware troubleshooting. The program included standard subroutines for use by associated test programs (i.e., input/output, time delay/time out, memory size determination, etc.).

The test executive program consisted of a preliminary instruction test that validated CPU operation by testing the appropriate machine instructions; a preliminary memory test that verified correct operation of memory; a binary loader test that loaded the test executive into computer memory, computed the check sum, transferred program control as directed, and indicated by a "halt" a check-sum or tape-parity error; and a test

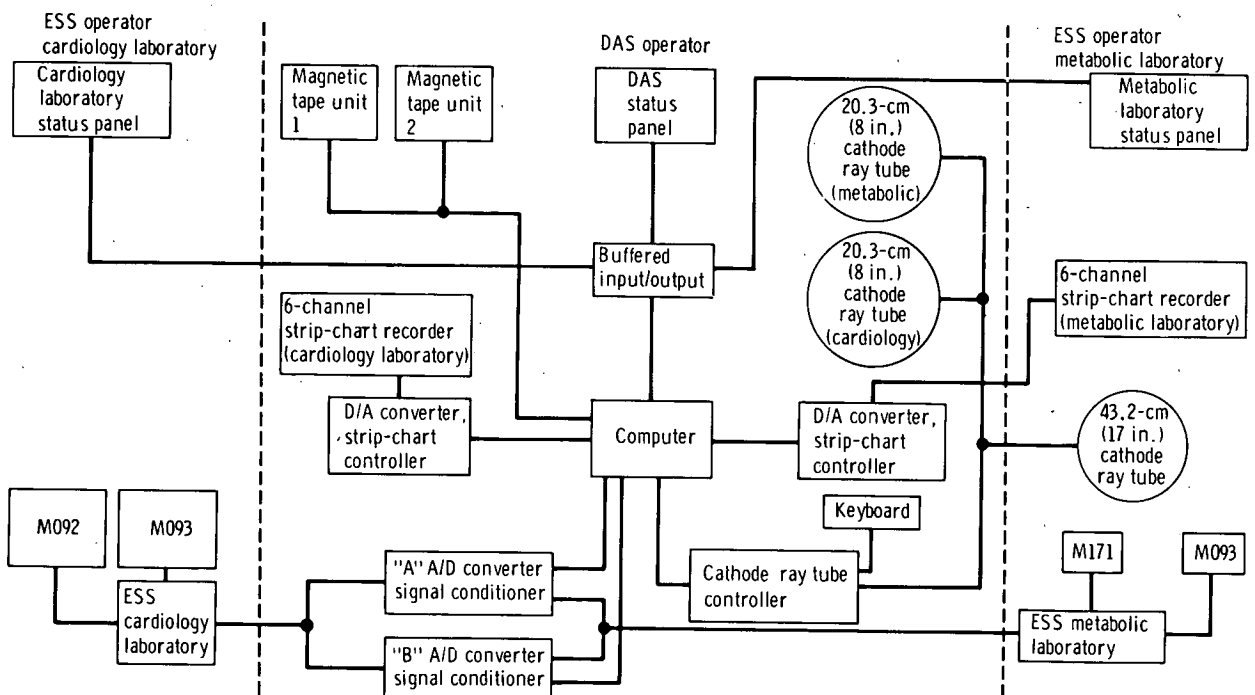


Figure 40.- Functional schematic of the primary DAS.

executive program itself that, in addition to providing test control and user interface, contained standard sub-routines commonly required by the associated test programs (i.e., input/output routines, "sense" switch routines, etc.).

The data acquisition program provided the capability to input, monitor, and record the experiment data. Data were displayed on the CRT monitors and strip charts in real time and recorded on digital magnetic tape. The tape formats were not in the standard PCM format and consequently had to be converted to standard PCM format through the decommutation program before processing or playback. Operationally, the data acquisition program was loaded from the test executive.

Because of the requirement to provide continuous recording from two experiments simultaneously using only two magnetic tape units, the PCM data file required by the off-line data analysis system could not be created in real time. Therefore, an off-line, stand-alone decommutation program was provided to build the PCM-formatted data file from the real-time data tape.

The data were processed from the laboratory data file, and PCM-formatted tapes were recorded by laboratory, by experiment, and by subject. Two passes through the laboratory data file (one pass for each laboratory) were required to retrieve all the information.

The data PCM tapes that were output from the decommutation program could be replayed for review when required. The data were always displayed on the large CRT and strip-chart recorder located in the metabolic laboratory. A forward time search could be initiated at any time during the run if certain parts of the experiment were not of interest.

The test programs provided for use with the primary DAS to facilitate troubleshooting and system maintenance consisted of 12 test programs specifically designed to test selected portions of the overall system. Specifically, these tests included direct memory access, magnetic tape, power fail/restart, A/D converter, D/A converter, CPU instruction, memory, priority interrupt module, real-time clock, CRT/keyboard, status panel lamp and switch, and a tape verification program to verify the quality of the magnetic tape used for data recording.

Secondary DAS

Objective. The objective of the secondary DAS was to provide a backup to the primary DAS in the acquisition, recording, and display of medical data collected on each crewmember during activities related to the Skylab major medical experiments (M092, M093 and M171). The secondary DAS was also located in both the cardiovascular and metabolic laboratories; however, it did not have any interaction between the two laboratories. The equipment in the cardiovascular laboratory supported only the LBNP and VCG experiments; that in the metabolic laboratory supported only the VCG and metabolic activity experiments.

Unlike the primary DAS, the secondary DAS did not consist of a central computer-controlled system; rather, it consisted of selected pieces of recording equipment capable of receiving and displaying the analog signals acquired from the ESS. Analog signals from the ESS were picked up at the primary DAS signal conditioners and routed in such a manner as to preclude interaction between the two systems, which could affect the integrity of the signals.

Equipment. In the cardiovascular laboratory, the equipment consisted of an analog magnetic tape recorder for recording all parameters associated with the VCG and LBNP experiments; a strip-chart recorder for VCG signals, delta pressure, heart rate, blood pressure, and leg volume changes; a biomedical display unit for displaying, in real time, an electrocardiogram signal from one of the three VCG signals available; and the necessary support equipment, such as time-code generators, preamplifiers, amplifiers, and power supplies (fig. 41).

In the metabolic laboratory, the equipment (fig. 42) consisted of a minicomputer, a flight-type analog recorder, an oscilloscope, and the necessary support equipment such as time-code generators, preamplifiers, amplifiers, and power supplies. The minicomputer comprised a controller, a disk memory unit, a central processing unit, and a tape deck. An eight-channel commercial recorder was provided for real-time recording and displaying of the VCG and metabolic experiment information.

The equipment in the cardiovascular laboratory was mounted in standard electronic racks that were shock



Figure 41.- Secondary DAS equipment in the cardiovascular laboratory.

mounted to the floor because of previous experiences in collecting LBNP data on board ship during the first Apollo missions. For these Apollo missions, the LBNP equipment and the recording equipment had been placed anywhere in the ship and had been subjected to severe vibrations.

The equipment in the metabolic laboratory was mounted in electronic racks similar to those of the cardiovascular laboratory. However, the racks in the metabolic laboratory were attached directly to the floor of the laboratory and no shock-mounting capability was included. This method was used because of the desire to use commercial equipment without modification whenever possible. The metabolic experiments had not undergone the same previous Apollo exposure as the LBNP experiment; the decision not to shock mount the equipment in the metabolic laboratory was made (and found to be satisfactory) because the laboratories themselves

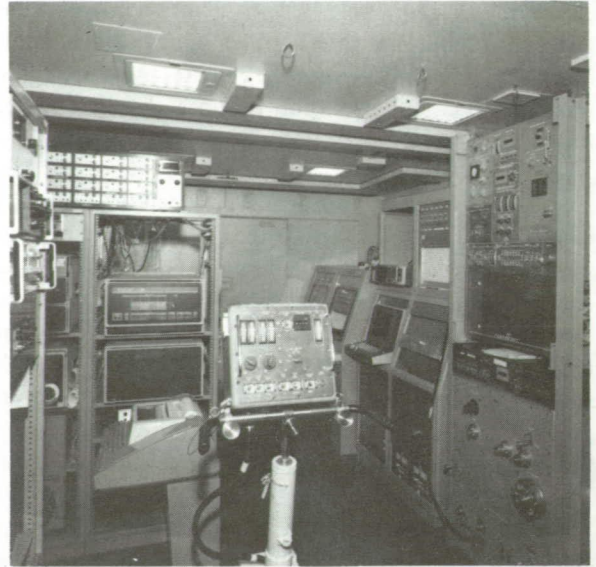


Figure 42.- Secondary DAS equipment in the metabolic laboratory.

had pallets that provided some shipboard vibration attenuation and because placement on board the ship was to be preselected rather than random.

UTILITY PACKAGE

Objective

The utility package provided a facility that housed all the equipment necessary to serve as an interface between the site electrical and water facilities and the SML, and that housed the vacuum source required for the cardiovascular and metabolic laboratories.

Basic Shelter

The basic shelter that served as the utility package was a U.S. Army Conex box. This box was a corrugated steel structure outfitted with skids to facilitate towing and with a set of double doors on one end to provide a full opening to the interior.

The external dimensions of the Conex box were 2.59 by 1.91 by 2.1 meters (8.5 by 6.25 by 6.88 feet) in height. The internal dimensions were 2.46 by 1.8 by 1.83 meters (8.08 by 5.92 by 6 feet) in height and provided a nominal volume of 8.35 cubic meters (295 cubic feet).

The SML Configuration

To meet the operational and use requirements established for the SML, modifications and equipment additions to the basic unit provided by the U.S. Army were required. These changes satisfied most of the electrical, water, vacuum, and miscellaneous requirements.

Electrical.- Investigations of the anticipated site uses indicated that the SML would be required to interface with sites providing either 208-volt, 225-ampere, 60-hertz power or 480-volt, 180-ampere, 60-hertz power. A connector panel, housing three four-pin connectors (two for the 208-volt input and one for the 480-volt input), was fabricated and installed on the rear wall of the Conex box (fig. 43). The input lines were routed to two main switchboxes, which allowed a selective capability of 208 volts, 480 volts, or OFF. These boxes were mounted along the sidewall of the Conex box.

From these main switchboxes, the power was routed through a power transformer (attached directly to the floor of the Conex box) to a power distribution and

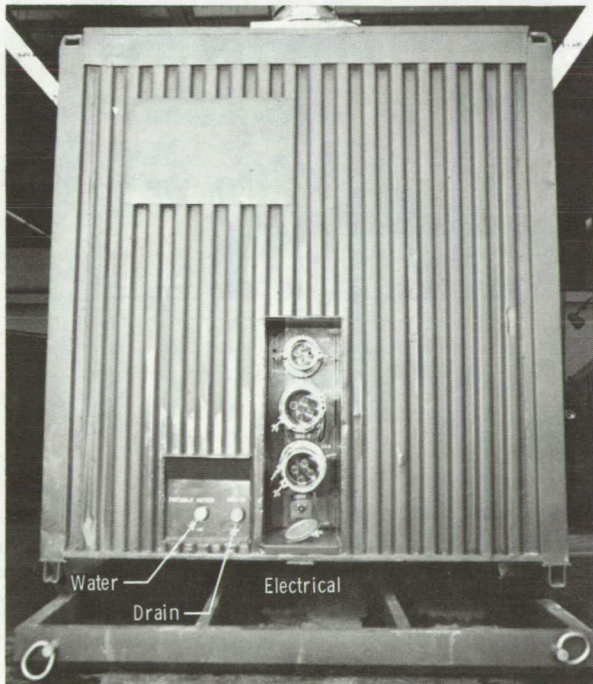


Figure 43.- Connector panels on the back of the utility package.

connector panel by way of a circuit breaker panel. This combination connector/circuit breaker panel was mounted at the opening end of the Conex box from floor to ceiling and provided the operator ready access to all connectors that provided power to the units for air-conditioners, basic line power, and the DAS power input required by the cardiovascular laboratory (fig. 44). Ground lugs on both the input connector panel and on the output side provided the capability to ground the entire system.

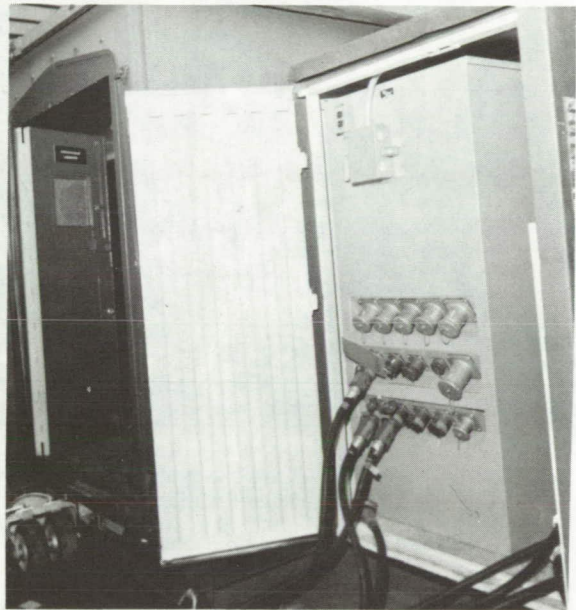


Figure 44.- Electrical connector panel on the front of the utility package.

Water.- A connector panel was installed on the rear of the Conex box to connect an input water line and waste-water-return drain line (fig. 43). The input water line was split inside the Conex box to provide hot and cold water. The cold-water line was routed directly to a connector panel at the front entrance (fig. 45) and was terminated with a connector identical to the water connectors provided as an integral part of the MUST units. The hot-water line was routed through a 0.151-cubic-meter (40 gallon) hot-water heater mounted directly to the floor of the Conex box and was terminated similarly to the cold-water line at the front water connector panel (fig. 45).

The drain line consisted of a connector on the front water connector panel (fig. 45) that was routed through the Conex box to the rear connector panel (fig. 43). Drainage of the hot-water heater was provided by a section of commercial garden hose attached to the drain valve of the hot-water heater and routed through the Conex box to the front.

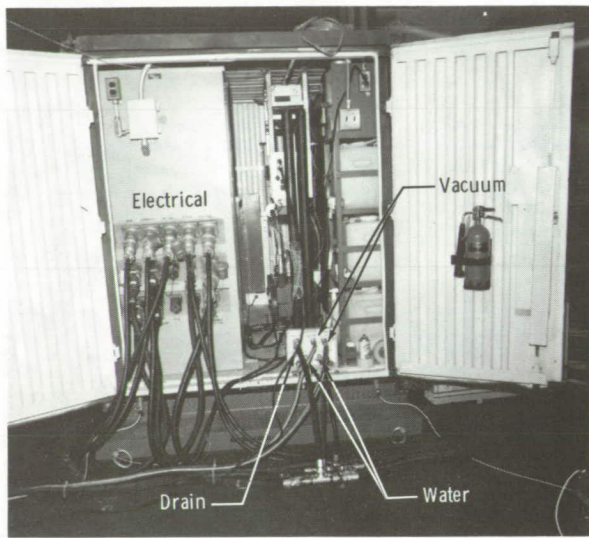


Figure 45.- Front view of utility package.

A potable water fountain, which had initially been installed in the operational medicine laboratory, was mounted on the outside rear of the utility package to provide a source of drinking water for the SML crew.

Vacuum.- The vacuum capability required by the cardiovascular and metabolic laboratories was provided by two vacuum pumps mounted directly to the floor in the center of the Conex box. These pumps were connected so that they could operate independently as separate systems or could operate together; thus, the failure of one did not compromise the system operation.

Because the requirements of the metabolic laboratory were more severe than those of the cardiovascular laboratory, the line from the pumps to the metabolic laboratory went from the pumps through two 0.153-cubic-meter (5.4 cubic foot) vacuum tanks to a connector panel (fig. 45) on the front end of the Conex box and to the laboratory. The cardiovascular line ran from

the pump to the connector panel to the laboratory. Two vacuum gages that showed the attained vacuum over a scale of 0 to 30 inches of mercury were installed in the utility package.

Miscellaneous.- An access door/panel was cut into the rear wall of the Conex box to allow access to the main switchbox. The front doors, which were flush closing doors, were modified to allow closing over the extended cabling when the SML was connected and ready for operation (fig. 46).

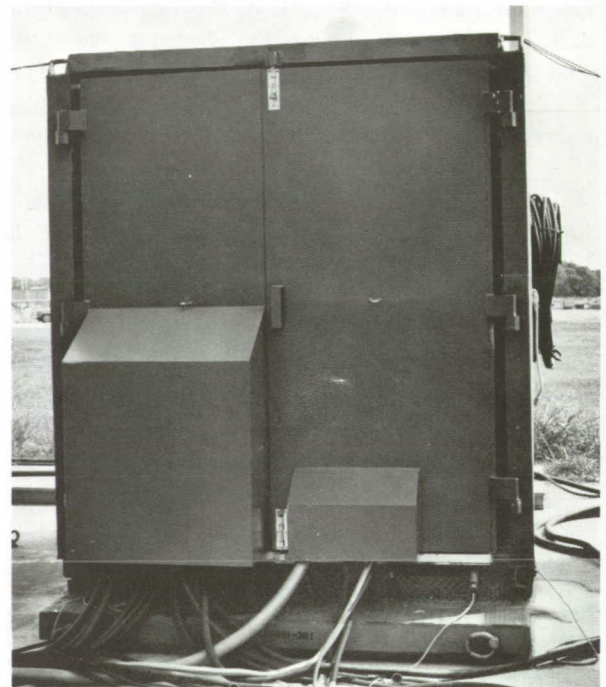


Figure 46.- Front view of utility package with modified doors.

A shelving rack constructed of angle iron was installed at the front entryway opposite the connector panel for restraining the eight 0.019-cubic-meter (5 gallon) containers of distilled water that were used by the various laboratories. A light fixture installed in the ceiling of the Conex box provided internal lighting. A vent fan installed in the ceiling provided air circulation and some temperature control, and a small toolbox located on the distilled water rack provided a source of convenient tools in the utility package area.

SHIPPING CONTAINERS

Objective

The shipping containers housed all the support equipment necessary for the assembly and operation of the SML that was not normally carried as an integral part of the six basic laboratory units and the utility package. The containers also provided a facility for performing field maintenance on the SML and its component parts.

The SML Configuration

Two Conex boxes were modified for use as shipping containers in support of the SML. One was configured as a workshop and the other as a shipping and storage facility.

Workshop. The workshop contained the tools, test equipment, and worktable area to permit SML personnel to perform that maintenance required in the recovery area (fig. 47). Shelving racks constructed of angle iron were installed on both sides of the shelter. A standard supply cabinet, a four-drawer file cabinet, and a workbench with drawers comprised the remainder of the storage and workspace area. A refrigerator attached to the floor of the unit was used to cool beverages for the SML crew and as a repository for the overflow samples collected for the blood experiment after the flight.

Two spare high-pressure bottles (one nitrogen and one oxygen) were stored in this shelter together with a spare vacuum pump; a test set for the BPMS; a recorder repair kit; spare VCG harnesses and sponges; sleep monitoring experiment equipment; the motor for the dynamometer calibrator; the electronics test equipment; all the small tools and spare parts (i.e., nuts, bolts, screws, screwdrivers, wrenches, drill sets, soldering guns, etc.) required for general maintenance; and general cleaning equipment such as soaps, scouring powder, rags, brushes, and vacuum cleaner.

An air-conditioning unit, mounted on the roof of the shelter, provided cool air for personnel. A distribution and connector panel to accept power from the utility package and route it throughout the shelter was mounted on the wall near the front side, and an illumination fixture provided interior lighting.

Shipping and storage facility. The shipping and storage facility provided the major items of equipment needed to support the SML at the recovery area. These



Figure 47.- Interior of workshop.

items were stored in three standard supply cabinets mounted along one wall of the interior of the container and on shelving racks constructed of angle iron installed along the opposite wall (fig. 48).

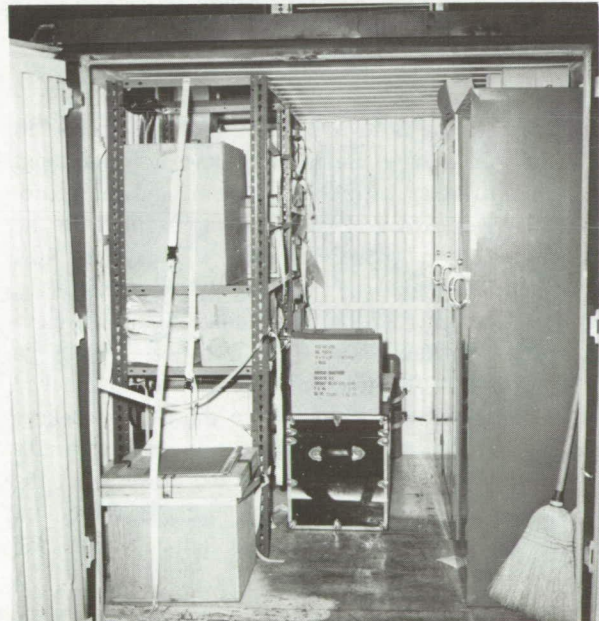


Figure 48.- Interior of shipping and storage facility.

Equipment located in the shipping container included spare punch drivers, multichannel analyzer, and oscilloscope for the bone mineral experiment; all the equipment needed for the stereophotogrammetric activity (i.e., stands, camera, and power supply); a spare CRT data display unit, CPU, and various spare parts for the primary DAS (including the DAS documentation); a spare power supply and switch panel for the mini-computer; spare dry-cell batteries; recorder paper and analog and digital magnetic tape; breakout boxes and cables for troubleshooting the major medical experiments; and cleaning materials (i.e., soap, scouring powder, brooms, mops, and rags). The spare air-conditioner for the laboratories was mounted to the top of the shipping container, and lighting within the shelter was provided by a trouble light on a standard extension cord.

SUPPORT EQUIPMENT

Objective

In addition to the major items of equipment comprising the SML, additional equipment was necessary to support use of the SML in modes of operation other than that for which it was primarily intended. Specifically, this included equipment necessary to transport the SML from location to location. Some of these items remained with the SML and others were provided by that facility where they were to be used.

Equipment

To prepare the SML units for transfer from JSC to Ellington Air Force Base, a crane and hoisting slings were used together with flatbed trailers and the appropriate tiedown devices (fig. 49). For loading into the C5A aircraft, the U.S. Air Force 463L system 40K loader, a crane, and the aircraft tiedowns were used (fig. 50). (More information on the loading system is given in the section entitled "The C5A Transport Test.") To provide power in flight, a converter system was attached to the aircraft power plant and to the utility package through one of the two 208-volt connector utility cables. Ground generators provided this power when the aircraft was quiescent. Unloading from the C5A required the use of the 463L system, a crane, flatbed trailers, and the appropriate tiedowns.

Loading onto the ship required use of the unit wheels, a sling, a tow bar, and a tow truck. Tiedowns were available on the ship. Unloading from the

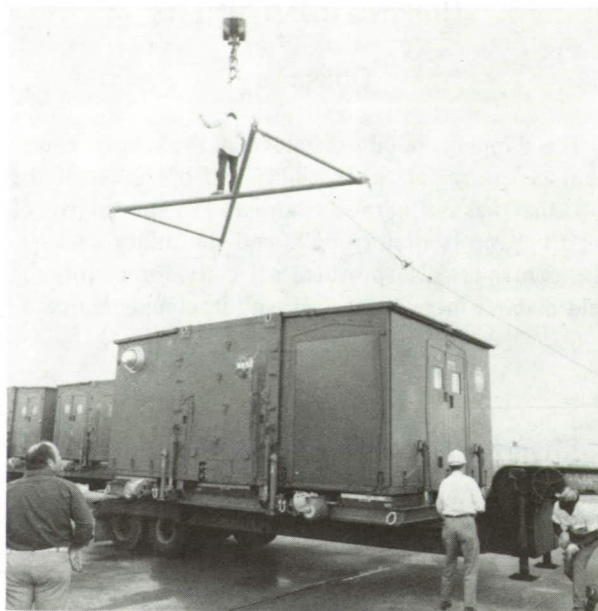


Figure 49.- The SML being readied for transfer from JSC.

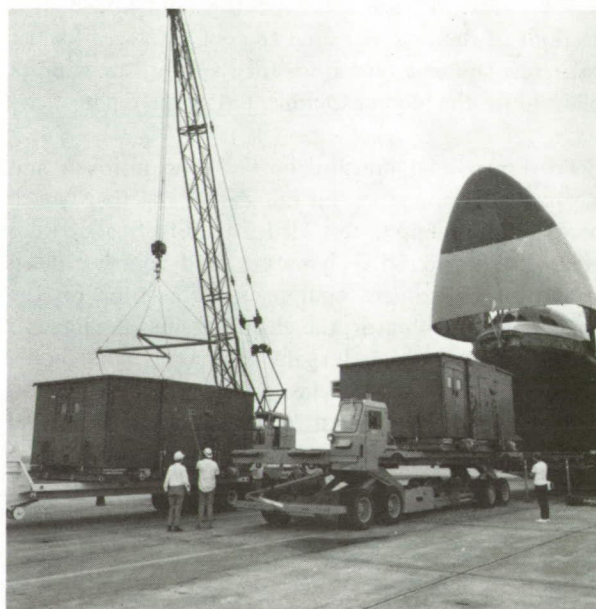


Figure 50.- The SML being loaded into the C5A aircraft.

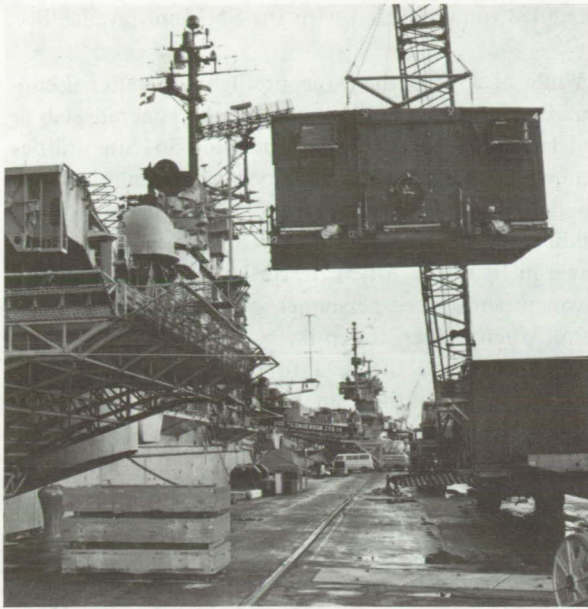


Figure 51.- The SML being loaded onto the U.S.S. *Ticonderoga*.

ship reversed the procedure, using the same equipment (figs. 51 and 52). In addition, because the shipping containers were unable to adequately carry the site-to-SML power cables, these items were mounted on and transported by shipping pallets (fig. 53). Nitrogen dewars used in conjunction with those samples being returned to JSC were also stored on these pallets.

Carried along in separate packing for use at the recovery area but not a part of the SML per se were a soundproof booth for conducting the audiometric examinations; the equipment used to evaluate isokinetic strength changes; the infrared photographic equipment used to obtain anthropometric data and enhance venous patterns; a vibrocardiographic system for recording the precordial vibrations in the frequency range of 0.5 to 100 hertz; a carotid pulsation system for sensing the arterial pulsations from the right or left carotid artery; a respiratory thoracic excursion system for sensing the respiratory excursions of the chest wall; and a pulmonary unit, breath analyzer, and mass spectrometer for obtaining special metabolic information.

OPERATIONAL CONCEPTS

The baseline operational concept for the SML required that it be capable of supporting a normal Skylab recovery, a secondary Skylab recovery resulting from a premature mission termination, the collection of preflight baseline data, and the collection of postflight baseline data until the preflight baselines were achieved.



Figure 52.- The SML being loaded from the U.S.S. *Ticonderoga*.

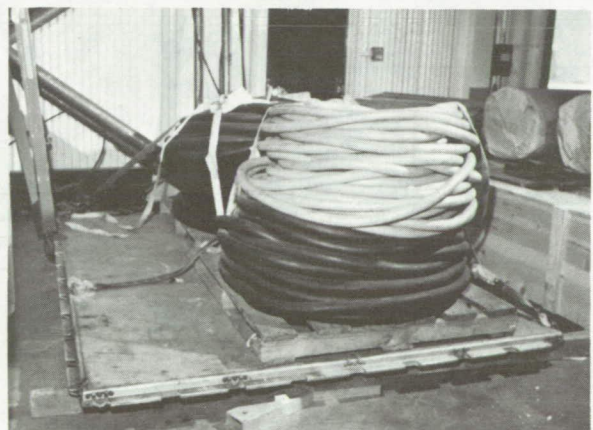


Figure 53.- Site-to-SML power cables on pallets.

PREFLIGHT BASELINE DATA COLLECTION

The SML was required to be ready to perform all the activities within each laboratory 30 days before each lift-off and at the same level and degree as it would perform them at the recovery site. A decision was made to use the medical facilities and laboratories at JSC to perform some of these tasks even though the SML was designed to fulfill the aforementioned requirements. Whereas the LBNP, VCG, metabolic, and bone mineral measurement experiments and the physical examination were routinely performed in the SML during preflight baseline data collection, blood and microbiology sample collection (with preparation and analysis done in the JSC facilities) and feeding in support of the mineral balance experiments were accomplished within the SML units only if the experiment requirement existed together with the SML usage on that particular day. In addition, some preflight data were taken in the SML before the "30 days before lift-off" requirement when a

scheduled run coincided with the SML unit availability.

While at JSC in the basic preflight operational configuration, the SML was located on the concrete slab or hardstand area directly behind building 36. Site utilities required for the SML (such as power, communications, fire detection, and water) were provided by existing building 36 facilities. The layout of the SML at JSC is shown in figure 54. When the SML was not occupied by crewmen, authorized personnel were permitted to work there. When either the primary or backup crew was required to be in the area for preflight testing, only those personnel authorized by the health-stabilization program conducted for Skylab were allowed in the roped-off secure area.

PRIMARY RECOVERY

Because of the requirements to support a secondary recovery, the SML was configured to support a primary

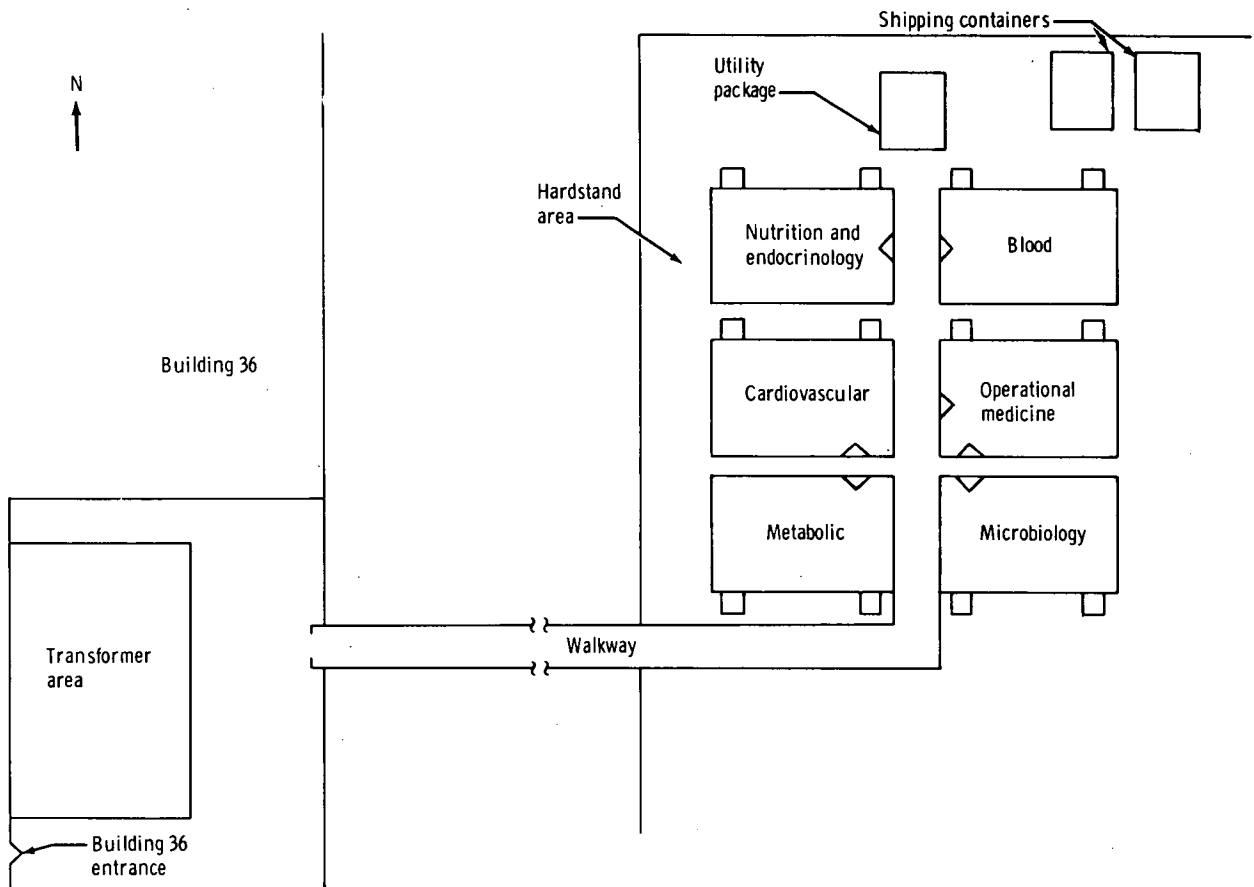


Figure 54.- The layout of the SML at JSC.

recovery early in the mission. This support was necessary because, if needed, the secondary recovery (a premature termination) preceded a normal recovery. Hence, the initial phases of operational readiness for the two recoveries were identical.

Approximately 5 days before lift-off, the SML assumed an operational posture and remained in that status until notification to move to the recovery area. All items of equipment, as specified by the stowage list, were verified as being in the assigned location in the SML except for those perishable and special-handling items that had been verified as being a "ready" mode in the appropriate controlled storage areas at JSC. All support and analysis equipment was verified as operable and packed for transport. The major items of equipment, however, were configured to allow for periodic exercising and/or checkout. All water lines were disconnected and stored for transport. The power and vacuum lines remained connected so that major items could be checked; so that freezers and refrigerators used to preserve perishables in transit could remain operable; and so that shelter lighting and air-conditioning could be sustained.

At a preselected time before normal splashdown, the SML was deployed from JSC to the recovery area. All units were prepared for transfer in accordance with procedures established and approved for this operation. All utility lines were disconnected and stored, and perishable and special-handling items were acquired from the assigned locations and transferred to the assigned storage locations in the SML. The batteries used to power the mass spectrometer in the metabolic laboratory were activated.

Rigging crews transferred the SML from the hard-stand location at JSC to flatbed trailers that transported the SML units to Ellington Air Force Base for subsequent loading into the C5A aircraft. Loading and tying down of the SML in the C5A was accomplished using the 40K loader of the 463L system in accordance with procedures established and approved for that operation. Immediately upon completion of aircraft loading, power cables were strung between the aircraft, the utility package, and the microbiology and nutrition and endocrinology laboratories to provide power to the refrigerators and freezers that contained the frozen foods and the perishable media.

The C5A aircraft, loaded with all the SML equipment and operating personnel, was then flown to the

designated port of embarkation for liaison with the primary recovery ship. The SML remained in the C5A until the decision to load the ship was received, and groundpower was made available at the airstrip to provide the required power capability to the various laboratories that were powered en route.

When the decision was made to transfer all equipment to the ship, all utility cables were disconnected and stored and all tiedowns in the aircraft were released. Offloading was accomplished using the 463L system and flatbed trailers. The SML was transferred to dockside and then hoisted on board the ship (the U.S.S. *Ticonderoga* for the Skylab 2 recovery (fig. 55) and the U.S.S. *New Orleans* for the Skylab 3 and 4 recoveries (fig. 56)) and placed at the predesignated location.

After positioning the SML on board the ship, utility connection was immediately instituted to provide power to the required freezers, refrigerators, and mass spectrometer. The rest of the SML was then deployed (in accordance with established and approved procedures) while the recovery ship was en route to the recovery area. This operation consisted of activation of all utility systems, checkout of all major medical experiments and their appropriate data systems, and checkout and placement of those test and analysis pieces of equipment that were transferred in the standard cabinet drawers in the SML. All checkout and preparation was completed before splashdown so that the laboratories were ready to receive the crewmen as soon as they were hoisted on board the recovery ship.

The operational requirements of the SML consisted of supporting the crewmen and the scientists in post-flight data collection, which was the primary objective of the SML. All crewmen entered the operational medicine laboratory where microbiology sampling, blood drawing, and physical examinations were initiated. Each crewman then continued along a postflight time line of activities in accordance with the representative time line schedules shown in figures 57 and 58.

In addition to supporting the crewmen, the laboratories also supported receipt of samples and items returned from Skylab and/or collected on the returning command module, such as the microbiology swabs, the urine sample containers, the in-flight medical support subsystem (IMSS) resupply container, experiment S015 (effects of zero g on human cells), student experiment ED31 (bacteria and spores), science demonstration SD10

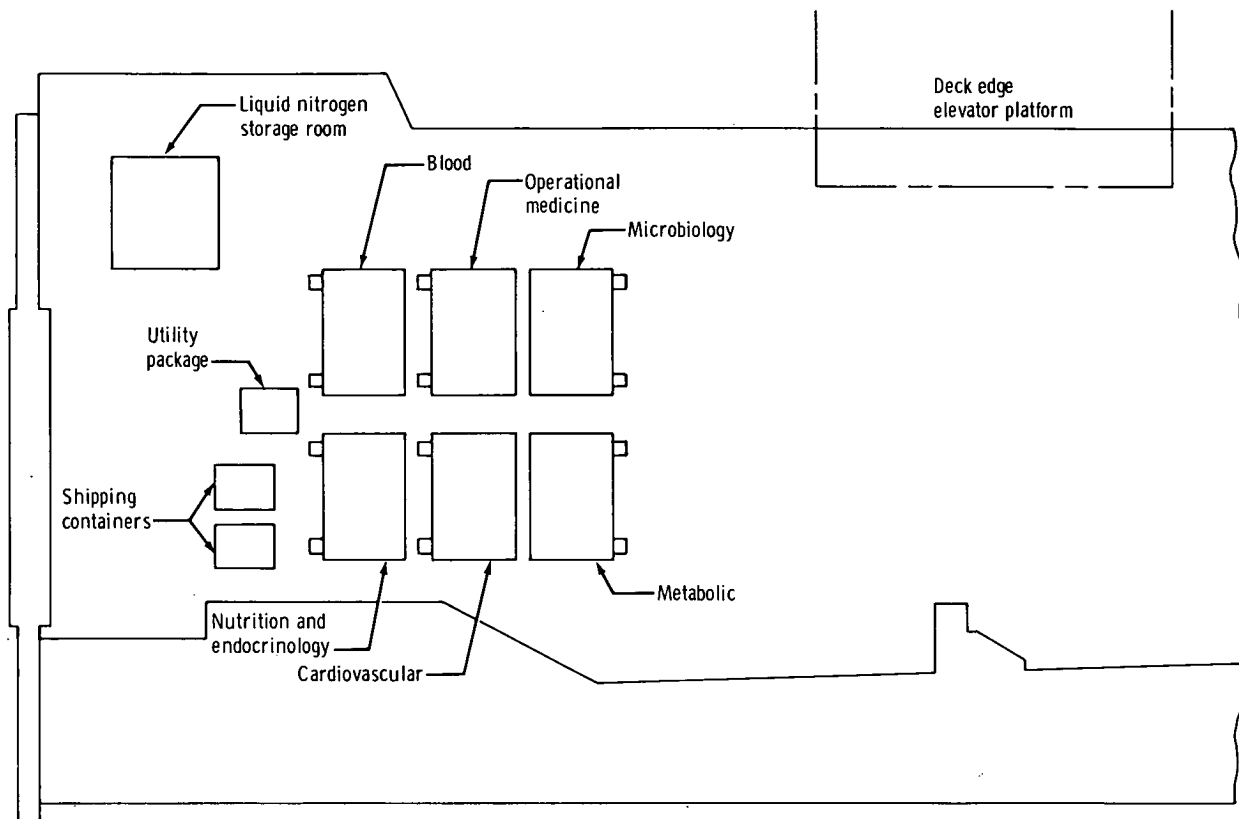


Figure 55.- The layout of the SML on the U.S.S. *Ticonderoga*.

(fish otolith), urine collection transfer assemblies, Skylab urine bags, and any contingency fecal and vomitus bags collected after deactivation.

After departure of the crewmen, the SML was deactivated and prepared for immediate return to JSC so that it could be used for the continuation of the postflight baseline data collection. All laboratories and utilities were prepared for transfer in accordance with the procedures established and approved for this activity. The SML was then offloaded from the ship onto flatbed trailers for road transfer to the airstrip and the C5A. Loading into the C5A was conducted using the 463L system similar to that done en route to the recovery area. The only difference between the two activities was that no power other than batteries to maintain the mass spectrometer vacuum was required because all perishables and samples were returned to JSC with the crewmen in a second aircraft using appropriate temperature controlled transfer cases. Upon arrival at Ellington Air Force Base, the SML was offloaded and immediately

transferred to JSC where it was deployed on the hardstand and reactivated to receive the crewmen for the continuation of the data collection activities.

The operational timetable for supporting the recoveries by the SML was modified somewhat (1) because the durations of the Skylab missions were actually 29, 59, and 84 days rather than the originally scheduled 28, 56, and 56 days; (2) because these extensions were real-time decisions; and (3) because postflight illnesses were experienced by the Skylab 2 crewmen and immediate in-flight illnesses were experienced by both the Skylab 3 and 4 crews.

The initial plan was to transfer the SML to San Diego, California, for the Skylab 2 and 3 missions and to Hawaii for the Skylab 4 mission for loading on board the recovery ship. Departure time from JSC for all three missions was to be approximately 7 days before recovery, thus allowing the SML to support a secondary recovery from JSC (using the C5A and the preselected

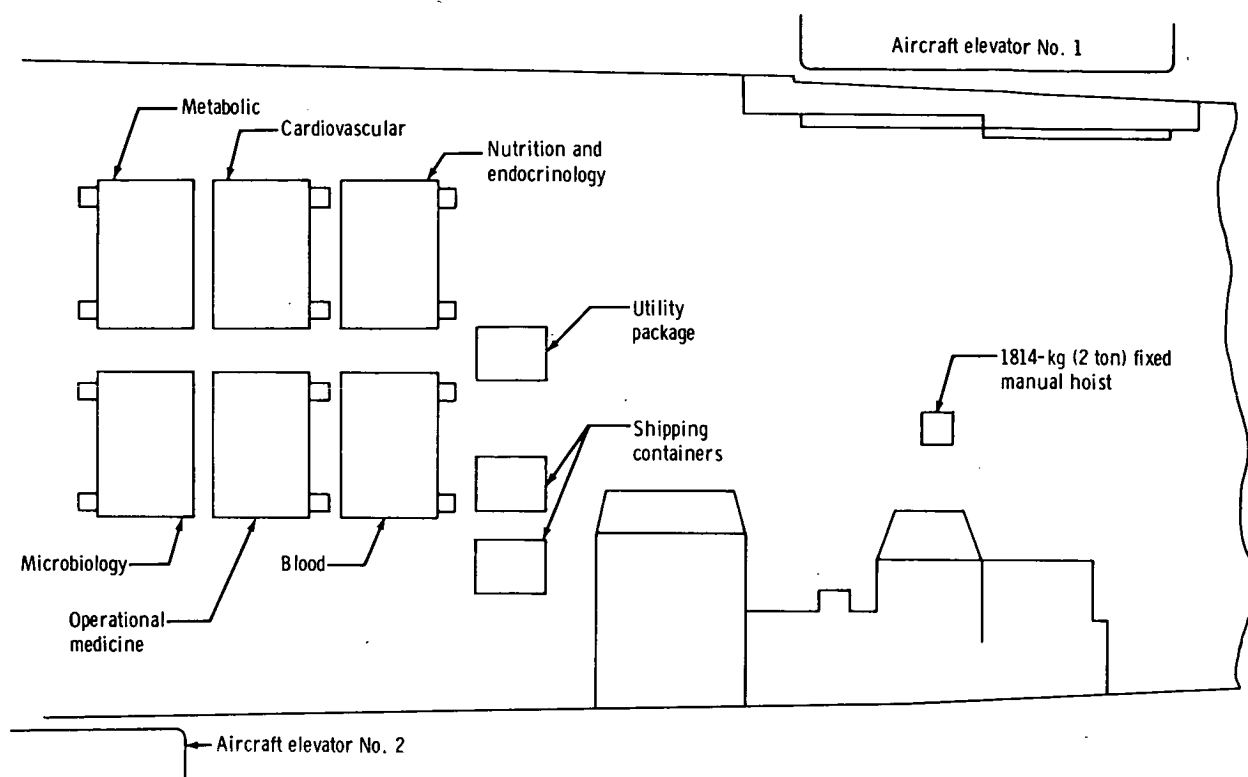


Figure 56.- The layout of the SML on the U.S.S. *New Orleans*.

island bases) up to the last week of the mission.

The Skylab 2 mission was accomplished according to this plan. The SML departed JSC on June 14, 1973, departed San Diego on the U.S.S. *Ticonderoga* on June 15, and supported recovery on June 22. It was used for the collection of postflight data on June 22, 23, and 24; arrived back at JSC on June 25; and reinitiated post-flight data collection on June 26 as scheduled.

Because of the illness experienced by all three Skylab 3 crewmen during their initial exposure to the space environment and the problems encountered with the reaction control system (RCS) thrusters of the command and service module (CSM), Skylab 3 was considered as a 28-day mission with weekly extensions to the desired 56-day limit. Therefore, for Skylab 3, the SML departed JSC on August 24, 1973, which was 30 days before the originally scheduled splashdown date. It was flown directly to Hawaii, rather than to San Diego, for loading on the primary recovery ship. From August 27 to September 13, the recovery ship tracked the Skylab flight so that each day it was available for recovery if a

decision were made to terminate the mission at the end of any given weekly extension. This secondary recovery site tracking was accomplished by the ship sailing in and out of Hawaii for 2 to 3 days at a time. On September 14, the recovery ship departed Hawaii and sailed to the normal recovery location approximately 400 kilometers (250 miles) southwest of San Diego, arriving there in time to support a September 25 splashdown. During the trip from Hawaii to the recovery area, the SML was configured to support a premature splashdown each day of the trip. The SML then supported recovery on the ship during September 25, 26, and 27; departed San Diego on September 28; and reinitiated the postflight data collection at JSC on September 29.

The Skylab 4 mission was classified as a 56-day mission with options to continue to 84 days again being made on a weekly basis. Hence, the SML departed JSC on January 10, 1974 (29 days before the scheduled end of the 84-day mission), and was flown to Hawaii for loading on board the primary recovery ship U.S.S. *New Orleans*. The ship departed Hawaii on January 13 and

	Crewman A	Crewman B	Crewman C
0	Microbiology	Microbiology	Microbiology
	M110	M110	M110
1	Meal	Meal	Liquid
		Physical	X-ray
2	Physical	X-ray	Stereo
	X-ray	Stereo	Leg volume
3	Stereo	M078	M092
	Visual function	Leg volume	M171
4	M078	M092	Physical
	Leg volume	M171	Meal
5	M092	Visual function	M078
	M171	Meal	Visual function
6	Meal	M133 on science pilot (only on night of recovery)	
7			

Figure 57.- Operations time line on recovery day (R+0).

arrived at San Diego on January 23; premature recovery areas were tracked each day of the trip. On January 27, departed San Diego on the U.S.S. *Ticonderoga* on June 15, and supported recovery on June 22. It was used for data were collected on board ship on February 8, 9, and 10, and the SML arrived at JSC for reinitiation of post-flight data collection on February 12.

	Crewman A	Crewman B	Crewman C
0800	M110	M110	M110
	Meal	Meal	Meal
0900		Audio Optical refraction	M078
		M078	Audio Optical refraction
1000	Audio Optical refraction		Leg volume
	M078		M092
1100	Meal	Leg volume	M093
		M092	M171
1200		M093	
	Leg volume	M171	
1300	M092		
1400	M093		
1500	M171		

Figure 58.- Operations time line for R+1.

SECONDARY RECOVERY

The SML was configured to support a secondary recovery requirement, in which the crewmen's stay in Skylab would be prematurely terminated and notice of such termination would be provided to the SML team at least 24 hours in advance of splashdown. If an emergency and immediate premature splashdown had occurred without 24-hour advance warning, the SML probably would not have been used to support recovery. The probability of support by the SML depended on how much advance notice could be received and how

available the C5A aircraft would have been. The decision to use or not use the SML would then have been made in real time.

As previously discussed, the SML was operationally ready approximately 5 days after lift-off. If the decision had been made to return the crewmen early, the SML would have been prepared for departure from JSC in a manner similar to that for normal recovery. The laboratories and utilities would have been secured, the perishable and special-handling items transferred from the storage locations to the SML, the SML transferred to the flatbed trailers for transfer to Ellington Air Force Base, and the SML loaded into the C5A using the 463L loading system.

In the C5A, the utility lines to provide the power required in flight would have been connected, and the remaining utility lines would have been deployed in preparation for subsequent use on board the C5A at an airfield in the vicinity of the recovery area (fig. 59). On arrival at this airfield, the power would have been transferred from airborne power to site facility power and the laboratories deployed in accordance with the procedures established and approved for that mode of operation. The crew would then have been received in the SML while still in the C5A, and the postflight data would have been collected in this configuration. Data could have been taken for as many as 3 days, after which the SML would have been flown back to Ellington Air Force Base for offloading and transfer to JSC for reinitiation of postflight data collection.

The success of the Skylab mission and its concomitant extensions resulted in the secondary recovery

mode never being used; however, the SML system was configured to support a premature termination if the occasion had arisen.

POSTFLIGHT BASELINE DATA COLLECTION

Upon return to JSC after recovery, the SML was redeployed on its hardstand, and all utilities were reconnected to the site facility supply so that the SML resumed the configuration used when preflight baseline data were collected. As with preflight operations, medical experiments and the physical examination were routinely conducted, only sampling was done for the blood and microbiology activities, and the mineral balance activities were performed in the SML only when those activities coincided with SML usage on that particular day.

PERSONNEL REQUIREMENTS

Two groups of personnel, operational and scientific, were required to support the SML. The operational personnel were responsible for SML setup and continued operation; the scientific personnel were concerned with data collection, analyses, and evaluation.

OPERATIONAL TEAM

The SML team responsible for setup and operation consisted of physicians, engineers, technicians, administrators, and quality-assurance personnel. These persons prepared the SML for all transfers and performed all basic deployment activities. The same personnel were responsible for the checkout of the major medical

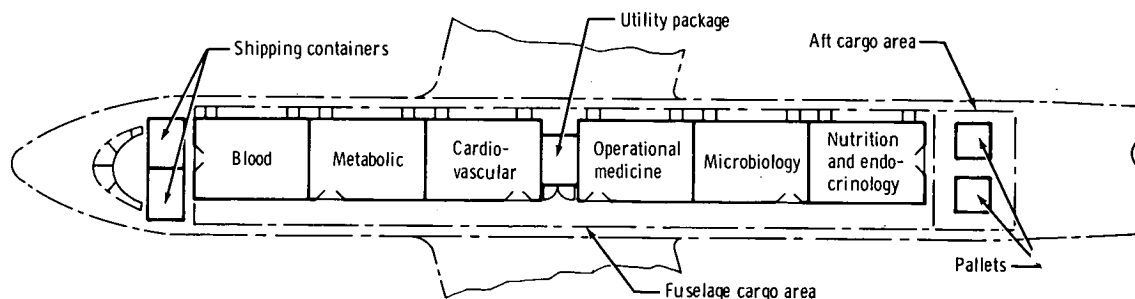


Figure 59.- The layout of the SML in the C5A aircraft.

experiment hardware and the activation and checkout of all major supporting equipment such as refrigerators, incubators, freezers, et cetera. The operational team was also responsible for overall performance of all activities within the SML whether performed at JSC during pre-flight and postflight phases or at the recovery site immediately after splashdown. The personnel who composed the operational team and a brief description of their responsibilities are as follows.

1. The medical officer was responsible for the overall operations conducted in the SML. He ensured the medical safety and physical well-being of the returned crewmen and directed all medical operations during medical emergencies. He determined whether any deviations to the time lines were required and what the deviations would be.

2. The recovery operations manager was responsible for all liaison required between the SML team and the U.S. Navy, U.S. Air Force, or site organization. He acquired the personnel necessary to transport the SML from one location to another and coordinated all loading and offloading operations with the primary recovery ship and C5A personnel. He ensured that all site facilities were made available to the SML as required.

3. The facility operations manager was responsible for overall control of the facility operations during SML operation at the recovery area. In areas other than recovery, he was responsible for the overall operation of the SML including checkout and maintenance, SML transfer, and overall facility operations.

4. The quality-assurance manager was responsible for inspecting and/or witnessing all fabricated or modified parts to ensure that they conformed to the latest applicable drawing, for witnessing all tests that were conducted, and for preparing reports on all problems or failures encountered.

5. The technical support officer was responsible for coordinating the performance of all operational and scientific personnel to ensure the orderly operations of the SML. He assisted the medical officer by ensuring the readiness of the SML for crew acceptance and provided necessary test support functions to the scientific staff before, during, and after testing. He coordinated sample receipt and delivery among FOD personnel and the various SML laboratories, maintained and ensured a proper data listing of digital tapes, and coordinated Applications Technology Satellite communications.

6. The technical staff consisted of a group of five engineers and three technicians responsible for the overall coordination, planning, implementation, and control of the SML installation, checkout, and maintenance activities; they were also responsible for the operation of the primary DAS and utilities package during data collection and data analysis at the recovery sites. This group performed the preparation for transfer and deployment procedures in support of each mission and provided the maintenance and operational assistance to the scientific personnel at the recovery site when required.

SCIENTIFIC TEAM

The scientific team consisted of those principal investigators, scientists, physicians, and technical personnel who were actually involved with the returning crewmen and/or the samples that the crewmen provided whenever experiments or operational tasks were being performed.

For this team, the needs varied as a function of each laboratory. The team performed duties as directed by the experiment requirements document for the respective experiment. The personnel responsibilities for each laboratory were as follows.

1. Blood laboratory: Five persons were required to operate the blood laboratory. They were responsible for collecting the required blood samples, for performing those immediate analyses as specified by the various experiment requirements documents, and for conducting the prerequisite operations on those samples returned from the recovery area to JSC for subsequent detailed analysis.

2. Cardiovascular laboratory: Five persons were required to operate the cardiovascular laboratory. They were responsible for the operation of the hardware used in collecting the LBNP and VCG postflight data.

3. Metabolic laboratory: Five persons were required to operate the metabolic laboratory. They were responsible for operating the hardware used in collecting the metabolic and VCG postflight data.

4. Microbiology laboratory: Four persons were required to operate the microbiology laboratory. They collected the microbiological samples from each crewman and from the returned command module; performed time-critical analyses on collected samples; conducted the prerequisite operations on those samples returned to JSC for subsequent analyses; and performed

the required analyses on all samples (crew, hardware, air, and illness events) returned from Skylab in the command module.

5. Nutrition and endocrinology laboratory: Eight persons were needed to operate the nutrition and endocrinology laboratory. They were responsible for overall food management for the crew when in the SML, for collecting and processing all biological samples (urine, feces, and vomitus), and for conducting bone mineral measurement activities.

6. Operational medicine laboratory: Two persons were required to operate the operational medicine laboratory. They were responsible for conducting the general physical examination and the audiometric and vision examination on each crewman.

TEST ACTIVITIES

Because commercially available equipment and Skylab-qualified hardware were used whenever possible, the test activities for the SML were significantly less than would have been required if a system using specially designed and unqualified hardware had been used. Three major tests were conducted as part of the overall SML program before it became a fully operational system: the C5A transport test, the mission support test, and the dry run test. The overall performance of the SML during these tests, the problems encountered as part of each test, and the changes implemented as a result of each test are discussed in the following sections.

THE C5A TRANSPORT TEST

The C5A transport test investigated various methods available for loading and offloading the SML from the C5A, tiedown schemes within the C5A aircraft, front- and rear-loading techniques, detailed placement of the individual units within the C5A, cable laying within the C5A, positioning schemes for the various units and the rigging equipment external to the C5A, and techniques of loading the ground transport units and transporting the system from JSC to Ellington Air Force Base and back to JSC.

The secondary objectives of this test were to determine the noise levels within each laboratory when the laboratories were loaded onto the C5A and all the SML air-conditioners were activated, and to make a qualitative determination of the environments experienced by the SML during takeoff, landing, and typical flight maneuvers of the C5A aircraft.

The primary loading systems tested were the U.S. Air Force 463L system 25K loader and 40K loader, as well as the Guppy loader that was used previously by NASA in support of Mercury, Gemini, and Apollo operations. The test showed that any of the three systems would be acceptable, but the 463L system 40K loader was the preferred system. This conclusion was based on the load capability of the 40K unit, its flexibility and positioning capability, and, hence, its ability to enhance loading and unloading times.

Multiple configurations were tested regarding the placement of the 40K loader, the crane, and the flatbed trailers containing the various SML units. The optimum configuration resulted when the 40K loader was positioned adjacent to the entry ramp at the front end of the C5A; the crane was positioned adjacent and to the side of the 40K loader; and the flatbed trailers were driven alongside the crane until their load was removed by the crane and placed on the loader. When this occurred, the unloaded trailer was removed and the next trailer was positioned for offloading. Once on the 40K loader, the shelters were manually pushed into the C5A and tying down of the loaded shelter began. This same configuration was used in the reverse mode for offloading the SML from the C5A.

Based on this configuration, it was determined that complete loading operations (including tiedown) could be accomplished in less than 2 hours and that offloading should require approximately 30 minutes. The reason for the large time discrepancy between the two activities was primarily the tiedown differences. Tiedown release was quick-disconnect, whereas tiedown itself was not. A second reason was that offloading did not require the accuracy of positioning by the crane onto the flatbeds that was required when the units were placed on the 40K loader for loading into the C5A. Actual operations were never timed to verify whether these times were met, but the knowledge that they could be met was important in the event of a secondary recovery in which speed would have been of the essence.

The shelters were placed in the C5A with adequate space on both sides of the shelters to accommodate the required cable-laying tasks (figs. 60 and 61). Adequate space also existed to perform the required cable hookups for the primary mode recovery (power cables for the freezers and refrigerators) and to assure that total utility placement with water, vacuum, and drain lines connected would be a feasible in-flight operation to support

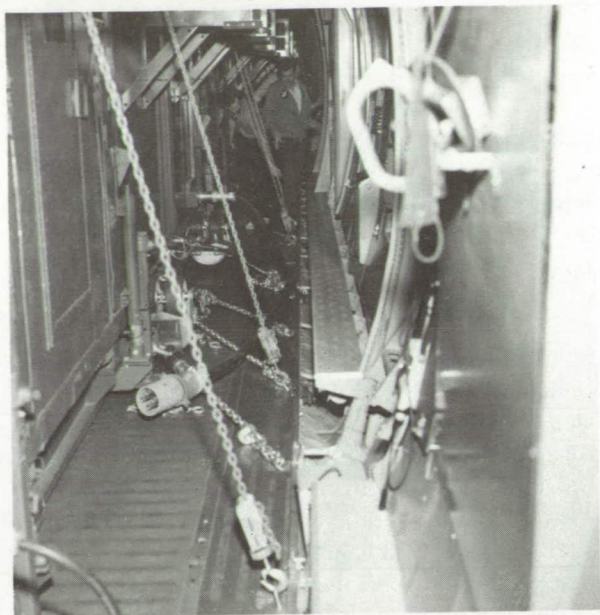


Figure 60.- Clearance at the rear of the SML in the C5A.

the secondary recovery. Because only one shipping container existed at that time, the availability of space for the second unit had to be ascertained by extrapolation. Measurement showed that enough space was available to handle the second shipping container, but that opening the containers and acquiring access to them would be difficult. This would necessitate offloading one of the two containers at the recovery site if the SML were to be used in a secondary recovery mode of operation. Because the secondary mode was never used, this problem was never encountered. There was no impact on the primary mode of operation.

Testing showed that rear loading was also feasible if required by contingency. This type of loading necessitated moving and accurately repositioning the 40K loader to the C5A rear entry ramp for each shelter loaded and/or unloaded, thus significantly increasing the amount of time required to perform either the loading or the unloading tasks (compared to the front-loading operation). Rear loading also necessitated removing the exhaust hoods that were mounted on two of the shelters to assure entry and removal clearance.

Noise tests showed that no problems existed for the personnel who were required to work in the shelters.

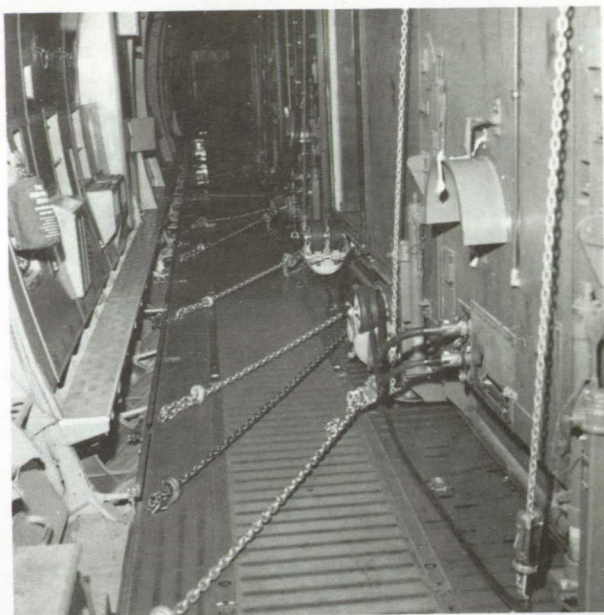


Figure 61.- Clearance at the front of the SML in the C5A.

With the shelter doors closed and with the shelter air-conditioners operating and the aircraft closed, the noise in the six shelters ranged from 68 to 72 decibels. With the aircraft nose and tail-loading doors opened and the aircraft airborne power unit operating, the values ranged from 70 to 77 decibels.

No problems were encountered when loading and unloading the flatbed trailers and when transporting them from JSC to Ellington Air Force Base and back to JSC. The loading scheme required that the SML units be placed on the trailers in a manner consistent with the C5A operational configurations (e.g., the nutrition and endocrinology laboratory and the microbiology laboratory were placed on the same trailer because they were to be the first two shelters loaded into the C5A). This expedited loading operations by minimizing trailer movement when loading.

As part of the transport test, the C5A flew approximately 40 minutes and performed a series of normal maneuvers before landing. The overall bank-and-turn activities were uneventful. Although the weather was overcast and light rain was falling, no turbulence was encountered and the environment in the SML was calm. There appeared to be little or no vibration in the cargo

bay of the C5A, and neither the landing nor the takeoff loads imposed any noticeable stresses on the system. Loose pieces of expendable equipment were left on the countertops of two laboratories before takeoff. After landing, an inspection revealed that this equipment was not disturbed. Based on these results, no problems were anticipated relative to using the C5A aircraft as the primary means for transporting the SML.

MISSION SUPPORT TEST

A shakedown test of the SML was conducted in conjunction with the Apollo 17 recovery operations; the objectives were to expose the SML to those operational environments that would be experienced during its performance and to determine the impact of those environments on its performance. The test objectives were to exercise the preparation for transfer procedures; the transfer operations from JSC to Ellington Air Force Base, to the port of embarkation, to the recovery area, and back to JSC; and the deployment procedures, which included test and checkout of the medical experiment hardware, the medical test analysis and support equipment (commercial equipment), and the primary DAS.

Preparation for Transfer Activities

The preparation for transfer activities included all the tasks associated with preparing the SML for transfer from JSC to the C5A and with being on board the primary recovery ship and preparing the SML for return to JSC. Preparation for transfer consisted of storing each laboratory and the shipping container according to the November 19, 1972, SML equipment/expendables stowage listing; verifying that all loose items in each laboratory were secured according to the preparation for transfer procedures prepared for each laboratory; and disconnecting and storing all interface lines according to the interface preparation for transfer procedures for JSC, the primary recovery ship, and the C5A.

Only one significant problem was encountered in the performance of these procedures. The pip pins used to retain the laboratory wheels in either the stowed or down position were extremely difficult to operate. The pin-to-hole tolerance was extremely tight and resulted in the need to hammer the pins in and out. The hammering, in turn, resulted in breakage of the handle portion of four of the pins and increased the difficulty of operation. In one case, a pin from the blood laboratory sheared so that its use during offloading was impractical. It was replaced by a bolt that also sheared during sub-

sequent offloading operations from the primary recovery ship. Although these pins were used only on the primary recovery ship, where the laboratories had to be rolled to and from the hangar deck elevator and their assigned location on the hangar deck, the difficulties encountered did appreciably increase the time line. Therefore, the pip pins and pin-to-hole tolerance were redesigned on return to JSC.

The procedures relative to operations within the laboratories were basically sound and required no significant revision. The operating procedures for the shipping container appeared to be adequate. However, only one shipping container was available, and this container was still in its initial configuration (i.e., an empty container with no shelving or storage areas). A good packing density but a poor use factor resulted because, to have access to the individual units, everything had to be removed immediately upon arrival at an operational site. Because of this problem, a second shipping container was added. One container was configured as a workshop and the other as a storage area. The decision to transport the site-to-SML power input cables on pallets outside the shipping containers also did much to relieve the congestion problem.

Transfer and Loading Activities

The transfer and loading activities included all the tasks associated with loading and offloading the SML onto the flatbed trailers, the C5A, and the primary recovery ship and with the actual transfer of the SML by each of the primary means of transportation. No significant problems were encountered at either JSC, Ellington Air Force Base, or North Island Naval Air Station (San Diego), primarily because both the rigging crews and the C5A loading crew had participated in the previously conducted C5A transport test.

At the U.S.S. *Ticonderoga*, however, loading was time consuming and reflected those errors and problems that occur when a complex team task is performed for the first time without any tested procedures for guidance and direction. As a result, procedures for this task were prepared for subsequent use in supporting the three Skylab missions.

During transfer operations, only one significant problem was encountered: the inability to provide in-transit power in the C5A aircraft to the microbiology laboratory. The C5A converter that provided the interface between the C5A and the SML utility package

operated satisfactorily. The problem was that wiring within the microbiology laboratory was incorrect and negated application of power to the required refrigerators/incubators. This error was corrected by a design change.

Deployment Activities

The deployment activities included all tasks associated with changing the laboratories from their transfer configuration to a configuration ready to check out the equipment housed in each laboratory. Deployment involved connecting all utilities between the site and the utility package, the utility package and the laboratories, and laboratory to laboratory.

This test covered deployment on board the primary recovery ship, on board the C5A where the system was deployed in the transit mode both for the primary recovery and for the secondary recovery, and deployment upon return to JSC (according to the interface deployment procedures for JSC, the primary recovery ship, and the C5A). These procedures were basically sound.

On board the primary recovery ship, access to the laboratories was somewhat inconvenient because of the height of the entrance of each laboratory and because laboratory wheels partially blocked the entry to the cardiovascular, metabolic, and microbiology laboratories. This high step, plus this interference, could have been a problem to returning crewmen, particularly since they would be required to use these entrances immediately upon return to one g. The medical requirement was to minimize any undue one-g strains and stresses until after initial testing had occurred. In addition, going directly from the hangar deck surface to the interior of the laboratories resulted in excessive amounts of dirt and grime being tracked into the laboratories. This was not acceptable for the scientific analyses being performed. To solve these problems, a raised platform covered with rubber mats was fabricated to provide a walkway between all the laboratories, thus eliminating the high entry step, the wheel interference, and the dirt-tracking problems (fig. 62).

Two problems were encountered in the C5A mode of operation. The first dealt with laying input power cable from the utility package to the site. This problem was corrected by appropriate coding of the various connectors and by modifying the procedures to assure that the critical cable was on the top, rather than the bottom,

of the pallet. The second problem was a wiring incompatibility between the site power source and the cables that resulted in a ground line with power applied to it. This problem was corrected by making an immediate change in the wiring.

Checkout Activities

The checkout activities included all tasks required in the checkout of the Skylab major medical experiment hardware (LBNP, VCG, and metabolic experiments), the primary DAS, and selected items of commercial equipment (refrigerators, freezers, incubators, and autoclave). These tasks were conducted on the primary recovery ship both upon initial installation en route to the recovery area and again at San Diego upon return from recovery, which was after approximately 30 days, or more, at sea.

Medical experiment hardware.- The Skylab major medical experiment hardware was checked out in accordance with the integrated test procedures that were originally prepared by the NASA George C. Marshall Space Flight Center but was modified to be compatible

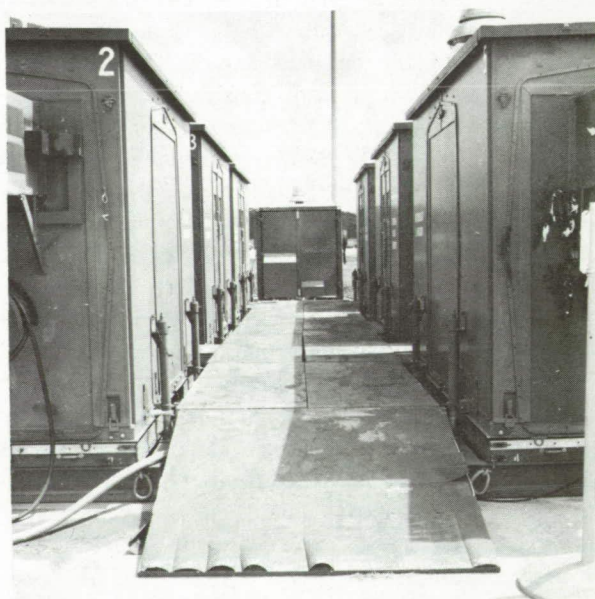


Figure 62.- Platform used to interconnect the SML laboratories.

with the SML facility and data system. The tests consisted of the following.

1. The LBNP-device pumpdown and calibration
2. The LBNP-device manual and automatic vacuum relief
3. The VCG electroshock protection test
4. The BPMS calibration and checkout
5. The LVMS calibration
6. The VCG simulated input test
7. The VCG pseudomission test
8. The MA calibration
9. The MA pseudomission test

No problems were encountered with either of the two LBNP-device tests. In addition, the system was connected to the DAS and data readouts of the two were compatible. During the electroshock protection test, personnel were shocked when they came in contact with the LBNP device and the adjacent storage cabinet. Analysis indicated a loose ground in the test box and use of an incorrect test lead (i.e., use of an alligator clip rather than a banana plug). Soldering the ground lead to provide a positive ground and use of the proper test lead resolved the problem.

During the BPMS calibration and checkout, leaking sense lines and fittings were encountered. Tightening these lines corrected the problem and it did not recur. The sense line leak was not believed to have been caused by the ship environment; this belief was confirmed when the problem did not manifest itself during subsequent tests after more than 30 days at sea. A similar problem of incorrect installation was encountered in the LVMS calibration test when bolts holding the calibration cylinder support strap fell free. Examination indicated that all the bolts were backed out so that they were engaged only by one thread. After the bolts were properly secured, the problem disappeared.

The VCG simulated input test was never successfully completed because an incorrect procedure was used and because the required input signal (1 millivolt peak-to-peak sine wave at 10 hertz) was apparently lost in the

extraneous noise on the ship. It was decided to discontinue this test in favor of the pseudomission test that used a test subject rather than a simulated input signal.

Although the MA calibration test was performed without problems, the MA pseudomission test did have problems. An initial problem was encountered with acquiring the proper subject and experiment identification. This difficulty was caused by a faulty signal ground in the ergometer; but, because this ergometer was not intended for use in the SML, no corrective action was taken. The second problem involved the absence of Korotkoff sound or display in the BPMS and was caused by an intermittent electrical connection between the microphone and the pressure transducer. A design modification was in preparation for the flight articles and was incorporated into the SML unit to correct this problem. The third problem was the absence of oxygen readings on both the MA and the DAS. This was found to be an error in the test procedures, which were subsequently corrected after return to JSC.

The DAS.- When the total unit was initiated (involving equipment in both the cardiovascular and metabolic laboratories), the systems in the two laboratories did not respond to each other. Investigation revealed that one of the connectors between the two laboratories was not properly seated. Reseating all the connectors resolved the problem at that time. However, it became evident that the problem would recur because the connectors were too closely spaced to ensure proper seating, and the connector panel was redesigned on return to JSC.

Two problems with the DAS were experienced in relation to the experiments. One concerned an inability of the DAS to respond to the signals being fed to it from the ESS. Investigations showed that the ESS-to-DAS cable had been fabricated without a ground return line. This line was installed and the problem was solved. The second problem was an instability of the experiment and subject identification that was experienced only in the cardiovascular laboratory. This problem developed because separate grounds existed for the 5-volt, 28-volt, and 10-volt sources as well as for the VCG. A common ground was run that took all sources to the same potential.

The DAS executive routine, which included all self-diagnostics, was run without incident. The decommutation of collected data, however, was found to be in real time and hence was unacceptable for use in the planned operational uses. A program change was required to

accelerate the decommutation process and was prepared and incorporated upon return to JSC.

Commercial equipment. Because the principal investigators and scientists were not present during the commercial equipment test phase, the commercial equipment checkout was limited to selected items such as refrigerators, freezers, incubators, the autoclave, and the water system, plus a visual inspection of all the items mounted and stored in the various laboratories.

The most significant problem experienced was that the water, although potable, did not taste good. Investigation revealed the cause was the hoses from the utility package to the laboratories and from laboratory to laboratory. As a result, hoses of a material that had no effect on the taste of the water were selected for future incorporation into the system. In addition, the location of the water fountain in the operational medicine laboratory tended to make control of water intake more difficult, and the water fountain was moved from that laboratory and installed on the rear of the utility package. In this location, the water went to the fountain directly from the site water supply and bypassed the water hoses that were part of the laboratories and which interconnected the laboratories.

No other significant problems were encountered with the commercial equipment, although some minor discrepancies were noted. Appropriate workarounds and SML changes were prepared, including the following.

1. There was no correlation between dial setting and temperature value on the three incubators/refrigerators in the microbiology laboratory or on the incubator in the blood laboratory. A correlation curve was prepared and taped to the outer surface of each item. However, upon return to JSC, the displays were changed to provide the readout directly in degrees.

2. The vent hood on the fecal handling station in the nutrition and endocrinology laboratory vibrated excessively, as did the kickplate on the refrigerator in this laboratory. Apparently, the screws were loose originally, because the problem never recurred after the screws were tightened.

3. There was no protective shield on the relief valves of the autoclave. A temporary shield was fabricated on the ship and a permanent shielding device was fabricated and installed after return to JSC.

4. The original commercial balances in the nutrition and endocrinology laboratory were inadequate and were subsequently replaced by another type.

Apollo Support Activities

Upon completion of the Skylab test activities, the SML was reconfigured to provide a recovery support capability for the returning Apollo 17 crewmen. This provided an opportunity to examine the SML items that would service Skylab under actual recovery conditions. This examination indicated several items that, if changed, would result in a more efficient operation during Skylab. These changes were applicable to the SML, in general, and to the specific laboratories as follows.

1. All laboratories were carpeted, and laundry storage was provided for the returning crewmen.

2. The interior configuration of the blood laboratory was redesigned to provide more tabletop and counter-top workspace. The incubator was replaced by a different model. A shelf for liquid containers was mounted above the sink.

3. Opaque curtains were placed in the operational medicine laboratory to support optical testing, and an additional chair and cot were provided for astronaut optical testing and resting. The shower was raised approximately 15 centimeters (6 inches) to facilitate drainage of water from the stall area.

4. In the microbiology laboratory, wall brackets to secure glass beakers during drying operations were installed, and the circuit breaker panel was relocated for easier access.

5. The ESS and MA were relocated in the metabolic laboratory so that they were mounted in a specially designed rack one on top of the other, rather than both directly on the floor. The drawers of the standard cabinets were used to store the calibration gas bottles.

6. The air-conditioner and humidity-stabilization system in the cardiovascular laboratory were changed to maintain environment within the Skylab specification.

7. In the nutrition and endocrinology laboratory, a refrigerator was added to maintain at proper temperatures the perishable supplemental food items that were carried for the returning crewmen.

As a result of all activities conducted by and with the SML during the Apollo 17 recovery operation, all primary objectives of the test were satisfactorily met. The environments to which the equipment was exposed appeared to have no serious effect on the performance of any hardware. The procedures were, in general, quite satisfactory for the intended tasks, although some real-time changes were required.

DRY RUN TEST

After the Apollo 17 recovery and after installation of all Skylab-required items and changes resulting from the mission support test, all data collection and analysis procedures were tested according to the scheduled recovery time lines. This test used three test subjects and the total SML operating team, exercised each medical experiment and activity, ran for the full 3-day capability, and included processing of the data tapes acquired through the primary DAS through the data processing facility personnel and protocols.

The most significant change resulting from this test was the recognition that the number of personnel

specified for operation in each of the laboratories was inadequate to perform the required tasks. Thus, changes in personnel requirements were authorized. These changes are reflected by the actual values specified in table I. Another significant change resulting from this test activity was the recognition of the need for an operations handbook and the creation of a post for the technical support officer who used the handbook. Basically, this handbook would serve (1) to control the samples returning from the orbital workshop relative to whether they should be processed in the SML or transferred to JSC, (2) to control the movement of samples collected in the SML, and (3) to control the basic movement of the crewmen themselves in relation to the established time lines.

A subsequent change was the decision to use standard commercial thermometers (rather than the BTMS ear probe) for acquiring body temperature of the crewmen as part of the LBNP and metabolic experiment protocols. The interior of the blood laboratory was also changed. Four standard cabinets were removed, a closed cabinet was installed under the worktable between the freezer and refrigerator, and the Plexiglas-enclosed

TABLE I.- CHANGES IN NUMBER OF SML PERSONNEL

Laboratory	No. of personnel	
	Planned	Actual ^a
Blood	5	9
Cardiovascular	5	7
Metabolic	5	7
Microbiology	4	7
Nutrition and endocrinology	8	7
Operational medicine	2	^b 8

^aAll figures cited are exclusive of the crewmen and represent general maximums rather than continuous values.

^bAs many as 12 persons were used in this laboratory during the first few minutes after the crewmen entered.

cabinet previously mounted above the worktable on the opposite wall was removed. Another change was the addition of opaque curtains to the cardiovascular laboratory and nutrition and endocrinology laboratory to provide better separation of work areas.

OPERATIONAL PERFORMANCE

The three categories of SML operational activities were (1) those conducted at JSC and on board the recovery ship to maintain the operational readiness of the system, (2) those conducted at JSC in which both preflight and postflight medical data were collected, and (3) those conducted immediately after splashdown at the recovery area in support of the Skylab 2, 3, and 4 missions.

OPERATIONAL READINESS

After completion of the mission support and dry run tests and before the start of the preflight baseline data collection activities, the primary activities associated with the SML consisted of incorporating modifications resulting from those tests, exercising the major medical experiments to maintain them in the required state of readiness, and conducting acceptance test procedures on the primary DAS. The acceptance test was performed after the mission support test because the DAS was the only specially designed item in the SML and its delivery was not scheduled until immediately before departure for the Apollo 17 recovery operations.

During the acceptance test of the DAS, 12 problems were encountered and corrected as the test proceeded. None were critical failures; most of the problems consisted of bent or broken connector pins, failed switches, procedural errors, tape reel misalignment, bad tape, and circuit board failures.

At the same time the equipment was being tested, minor problems were experienced with air-conditioners that froze, with connectors that had bent and/or broken pins, with pressure systems valves that leaked, with a BPMS system that registered incorrect readings twice, and with an MA spirometer that malfunctioned during a metabolic test. These problems were corrected by routine maintenance activities.

On board the recovery ship and before return of the Skylab 2 crewmen, significant problems were encountered with the primary DAS. The executive tape would not load the program beyond step 97, and tape

unit 1 would not play back tapes produced on tape unit 2. The executive tape was replaced with the spare tape and the program ran to completion; however, at the completion of the test, more than the allowed number of parity and compare errors had occurred. The tape unit 1 capstan was misaligned because of a loose retaining locknut/screw. This screw was tightened and the problem was resolved.

The second problem (lack of data playback capability) was not resolved until after return to JSC. However, this problem imposed no constraint on the postflight data collection activities and did not compromise any of the mission requirements. Data playback in the recovery area was not a requirement, and playback could still be done on the same unit if there was an emergency requirement. Extensive troubleshooting was required before it was found that tape unit 1 had a shorted transistor on the track 6 amplifier, which disabled the amplitude clipping level.

On board the recovery ship and before the Skylab 3 crewmen returned, the temperature controller for the fecal freezer in the nutrition and endocrinology laboratory failed and had to be repaired. Also, three problems with the DAS were experienced. These difficulties consisted of a rewind failure that was resolved by cleaning and reseating the printed circuit for tape unit 2 in the CPU; a power-supply failure resulting from an over-voltage setting that was resolved by using the spare power supply unit; and a loss of a time word that was resolved by cleaning all connectors in the unit.

Before the return of the Skylab 4 crewmen, minor problems occurred with the experiment hardware: the ESS and LBNP-device chamber temperature became erratic, the tension cable of the LVMS legband slipped off the drum, and the exhale sample pressure valve and the air inlet valve of the MA became difficult to operate. These problems were corrected by normal maintenance. Significantly, all repairs throughout the operational-readiness phase were completed so that the equipment was ready to operate during the critical data collection phase.

Before arrival of the crewmen, the SML vibration environments were measured during the primary recovery ship operations to determine the relative severity of vibrations caused by the U.S.S. *Ticonderoga* and the U.S.S. *New Orleans* and to correlate vibration input levels to equipment performance and operational requirements. For these tests, accelerometers were

placed on the hangar deck of each primary recovery ship and in various locations in the cardiovascular laboratory.

Data were recorded at ship speeds from 2.5 to 10 m/sec (5 to 20 knots) in 2.5-m/sec (5 knot) intervals; two additional measurements were taken at operational speeds of 4 and 12.5 m/sec (8 and 25 knots). The vibration levels measured at all locations were very low (less than 0.06-g peak), and the major vibration frequencies were less than 30 hertz. When the acceleration levels measured on the primary recovery ship were compared to the vibration design requirement of the SML, the measured accelerations were well below the specification levels.

PREFLIGHT AND POSTFLIGHT DATA COLLECTION

During the preflight and postflight data collection phases, the SML was routinely used to conduct the physical examination and the experiments on bone mineral measurement, LBNP, VCG, and metabolic activity. Blood samples and samples for microbiology experiments also were taken as scheduled, and body-waste samples were collected and diet control was enforced in support of the mineral balance experiments when required in conjunction with a scheduled activity in the SML. As anticipated, no problems were encountered in performing the tasks associated with the sample collecting or with the care and feeding of the crewmen. Similarly, no problems were encountered during the physical examination or with the bone mineral experiment, for which 81 runs were performed on the prime and backup crews.

For the major medical experiments (LBNP, VCG, and metabolic), a total of 271 data runs was conducted. Because both a primary and a secondary DAS were used, the amount of data lost was extremely low. For the metabolic experiment, one run was lost on the primary DAS, but all data were available through the small computer. For the LBNP experiment, one heart rate record was lost in both the preflight and the postflight phases, and one loss of legband data was encountered during the preflight test. Thus, data recovery for these three experiments was approximately 99 percent and, perhaps equally as significant, in no instance was a total data run lost.

Although the success rate of these experiments and the associated data collection systems was significantly high, some problems were encountered during the data

runs but were resolved by normal maintenance. In the pre-Skylab 2 phase, only three problems were encountered; all were associated with the primary DAS. Two of the failures were traced to failed integrated circuit cards, and one failure was traced to a failed power diode. During the period between the Skylab 2 and 3 missions, problems were experienced with some of the LVMS legbands. Tension-restraining cables broke, and cable connectors would not lock and operate properly; a VCG umbilical cable would not lock in place at the SIB; and a tape wound off the reel backwards on the primary DAS tape unit. Normal maintenance resolved all the problems except the DAS tape problem, which required the rewind card to be redesigned.

During the period between the Skylab 3 and 4 missions, the only noteworthy problems were associated with the primary DAS. Tape unit 2 would not record properly and this was isolated to the record software associated with the rewrite of a data record after an error; a CPU power supply failed and was replaced by a spare; an input/output card in the CPU chassis failed and was replaced; a controller rewind error was encountered that was traced to a wiring error; an integrated circuit in the rewind board on tape unit 1 failed and was replaced; a tape head on tape unit 1 failed and was replaced; the remote rewind on tape unit 2 failed and was repaired; capstans and tape guides from both tape units were replaced; and a special diagnostic and error correction routine was written into the software to correct a magnetic tape unit design fault that caused continuous magnetic tape errors to occur.

Although data collection and retrieval relative to the major medical experiments were significantly high, the primary DAS did continue to exhibit recurring problems with its magnetic tape units that required considerable troubleshooting. One early symptom was an unexplainable system error that could not be duplicated; therefore, the cause could not be pinpointed. An investigation revealed that the file tapes were having scrambled data that gave the data a skewed appearance when listed out.

Further investigation revealed a software problem on decommutation that caused data scrambling once the decommutation program encountered a rewritten record on the master tape. The software problem was fixed, but the symptoms continued to occur; however, when a second decommutation was attempted, the problem usually disappeared. This indicated that, with the software fixed, the problem was an intermittent hardware malfunction. Later symptoms of the problem were that

the master tapes had scrambled data and nondecom-mutable data recorded on them with the same indication that record lengths were too long or too short. After detailed investigation, the problem was discovered to be in one of the magnetic tape units in which the read strobe circuit was falsely retriggering. This retriggering was internal to the one-shot multivibrator.

The tape unit read and write electronics were reviewed thoroughly to determine what conditions could cause this intermittent problem. This review revealed some violations of the rules of good logic usage; inadequate stress limitation margins; and use of outmoded, noise-sensitive digital transistor logic elements.

The conclusions drawn from this investigation revealed that some significant changes would be required to the DAS that might or might not resolve the problem. Because only one mission remained, the decision was made to keep the existing system and to suffer the inconveniences of having to perform multiple decom-mutations to get a good, workable tape rather than to risk losing the high success rate of data collection already accomplished. The wisdom of this decision, which was made during the Skylab 4 mission, was proved when the 21 recovery and 84 postflight data-collection runs were conducted without a loss.

RECOVERY DATA COLLECTION

During the recovery operations, when the crewmen were still on board the primary recovery ship, all data collection activities were successfully completed and no failures were encountered in which data were lost. The physical examinations, the sample collections and their concomitant analyses and preservation activities, and the medical experiment data runs were all completed as required. For the major medical experiments (LBNP, VCG, M093, and metabolic experiment), 63 data runs were conducted and no data were lost.

Although no data were lost, problems were encountered that required workarounds and/or modifications to ensure that the overall objectives of each of the laboratories were met. The BPMS cuff used to collect blood pressure data during an LBNP run started to give intermittent high systolic readings and was replaced by the manual blood pressure system. The BPMS used to collect data during a metabolic experiment would not produce any Korotkoff sounds and was replaced by the spare. The failure was traced to a broken wire in the micro-

phone circuit, and the wire was repaired on return to JSC.

A diode failure in the recorder of the secondary DAS in the metabolic laboratory resulted in a failure of the Z-fold mechanism. This malfunction resulted in the operating crew collecting the paper in a box on the floor rather than having the paper neatly folded. On return to JSC, this item was repaired by replacing it with the Z-fold unit from another recorder. During the Skylab 2 recovery operation, the incubators in the microbiology laboratory would not hold constant at the 310 K (37° C) level. This instability was attributed to a relay that chattered because of the vibration of the ship. The controller system was redesigned between missions to a solid-state controller, and no recurrence of the problem was noted.

In the nutrition and endocrinology laboratory, the equipment used to support the bone mineral measurement did not operate properly in any mission because a mounting screw, which was too long, shorted out one of the printed circuit cards of the system. The researchers used the small computer in the metabolic laboratory on a time-sharing basis and were able to meet all of the objectives. In the blood laboratory, both the flame photometer and the co-oximeter failed to work properly; however, these failures did not cause any undue problem. The flame photometer was to be used for an immediate electrolyte assay if conditions warranted, but this was never required. The co-oximeter was too fragile for the environment (as had been suspected), and its function had to be satisfied by other equipment carried on board.

The air-conditioners continued to freeze up on board the ship, resulting in other-than-optimum temperatures in the laboratories. With the high temperatures in the recovery area and the high occupancy rates in each of the laboratories, immediate reparation was warranted. Between the Skylab 2 and 3 missions, freeze kits were designed and installed in each of the units to eliminate the problem. These kits measured the temperature on the unit itself and disengaged the compressor whenever ice began to form on the coils.

CONCLUDING REMARKS

The collective opinion of those who used the SML was that the laboratory satisfied its basic requirements. The users indicated that the existence of the SML

enabled them to do significantly more scientific work and collect more data than was possible in previous space-flight recovery operations in which such a capability did not exist.

Many of the scientists believed that the greatest advantage of the system was the stability it provided with the equipment permanently installed. The existence of the SML eliminated the previous recovery operational problems and failures associated with crating, uncrating, assembling, and disassembling experiment hardware each time the units were moved. The SML provided consistency of appearance and configuration, eliminated the need to run cables haphazardly, and provided a familiarity of appearance so that any test at any location appeared to be no different from that performed in the scientist's laboratory or in the crew training quarters. The SML provided a stable environment not subject to the competing space requirements and availability of the recovery ship; the laboratory enabled checkout to be delegated to personnel other than the scientists; and, perhaps most important, the SML resulted in less fatigued and frustrated scientists and thus allowed them to concentrate more on the scientific aspects of the assignment and less on the problems of operational assembly and checkout.

Scientists who used the SML made only one significant criticism. They believed that changes in scientific requirements had caused difficulty, rather than failure of the basic design of the SML. For example, the need for the crew to leave the general area of the SML and go to the sickbay for more tests and activities tended to break the continuity of operations and to make control of the time-line flow more complex.

The initial requirement was to perform all the tests

and activities in the SML except the required X-ray, which was scheduled for the sickbay facility of the recovery ship. For the Skylab 2 mission, this operational philosophy was followed. For the Skylab 3 and 4 missions, however, additional tests such as portions of the rotating litter chair experiment and the isokinetic strength test and infrared photographic tests were requested by the scientists, based on needs indicated in real time by the results of each previous flight. Installation of the equipment for performance of these tests in the SML was not practical from a space and usage standpoint; therefore, the decision was made to use the available sickbay space on the recovery ship. Hence, the items were transported to the recovery ship in separate crates (as during the Apollo missions) and assembled, checked out, and used in whatever space was available in the sickbay, thus partly compromising the major benefits of the SML (i.e., consolidation of operations and permanency of operation).

Some minor changes were also recommended: better soundproofing in the operational medicine laboratory, more shelves in the blood laboratory, and better odor control at the fecal handling station of the nutrition and endocrinology laboratory. However, these shortcomings were more than compensated for. The scientists believed that blood experiments on human immunity and hematologic effects involved tests that could not have been performed without the SML. The microbiology activities included diagnostic support for health stabilization on approximately 10 persons, another task that could not have been accomplished without the SML. Use of the SML reduced the processing time for samples from more than 48 hours to fewer than 12 hours, thus reducing the probability of deterioration of the samples. The cardiovascular and metabolic data collection was significantly greater in quality and quantity than had been experienced before.

Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas, December 11, 1974
948-90-90-89-72



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